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ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mī'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g=2.205 lb.
km²	square kilometer(s)	
kVp	kilovolt peak	
m³	cubic meter(s)	
mA	milliampere(s)	
mCi/mi²	millicuries per square mile	0.386 nCi/m² (mCi/km²)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi²	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m²	nanocuries per square meter	2.59 mCi/mi²
pCi	picocurie(s)	10^{-12} curie =2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 12, Number 6, June 1971

Radiological Health Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Environmental Protection Agency
Atomic Energy Commission

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ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

Reports

Radioactive Waste Discharges to the Environment from a Nuclear Fuel Reprocessing Plant

Joe E. Logsdon and *John W. N. Hickey*[1]

The Nuclear Fuel Services fuel reprocessing plant has been in operation since 1966 and has provided valuable experience in waste management problems related to this type of facility. The large quantities of radioactivity which must be controlled at a nuclear fuel reprocessing plant virtually eliminate discharge-and-dilution as a satisfactory method of disposing of radionuclides which concentrate through environmental media. Radionuclides such as strontium-90, ruthenium-106, cesium-137, cesium-134, cobalt-60, tritium, and krypton-85 have been found in environmental media around NFS. These indicate that pathways to the public do exist as a result of operation of the facility. However, studies to date have indicated that typical population doses in the vicinity of NFS are not significantly different from doses received in other portions of the State.

On April 30, 1963, the Atomic Energy Commission (AEC) issued to Nuclear Fuel Services, Inc. (NFS), a permit for construction of the first commercial nuclear fuel reprocessing plant in the United States. Construction was completed in June 1965, at which time receipt and storage of spent reactor fuel began. The AEC granted a provisional operating license in April 1966, and operations began on April 20, 1966. Two other commercial reprocessing plants are under construction in Illinois and South Carolina, and others are being planned.

The function of a nuclear fuel reprocessing plant is to salvage reusable materials from spent reactor fuel. Nuclear reactor plants discharge to the environment a very small portion of the radioactivity generated by their operations. The remainder of the radioactivity is contained within the fuel cladding. A reprocessing plant chemically separates plutonium and unused uranium from the associated fission products in the spent fuel. The uranium can be reused as reactor fuel, and plutonium is stockpiled for possible future use as reactor fuel. The remaining waste materials include radioactive fission and activation products. Reprocessing operations include the disassembly of fuel bundles and the cutting and dissolution of fuel rods. Consequently, a large amount of potentially releasable radioactive material is involved, as opposed to reactor operations where radioactive fission products are contained within the fuel cladding.

The purpose of this report is to provide a general description of the NFS facility and information concerning the discharge of radioactive materials to the environment by the plant, and to relate these discharges to plant operations and discharge limits. As required by the AEC, Nuclear Fuel Services routinely prepares operating reports which include information concerning amounts of radioactive waste released to the environment. These reports are the principal source of data for this report.

Site description

The NFS reprocessing plant is located near the center of Western New York Nuclear Service Center (WNYNSC), in the township of Ashford, Cattaraugus County, New York. A map of the site is provided in figure 1. Western N.Y. Nuclear Service Center is a 3,331-acre, State-owned preserve, 30 miles southeast of Buffalo. It is completely

[1] Mr. Logsdon is a health physicist with the Environmental Protection Agency, and Mr. Hickey is a student at Notre Dame and was a COSTEP with the U.S. Public Health Service, Bureau of Radiological Health, during the summer of 1970.

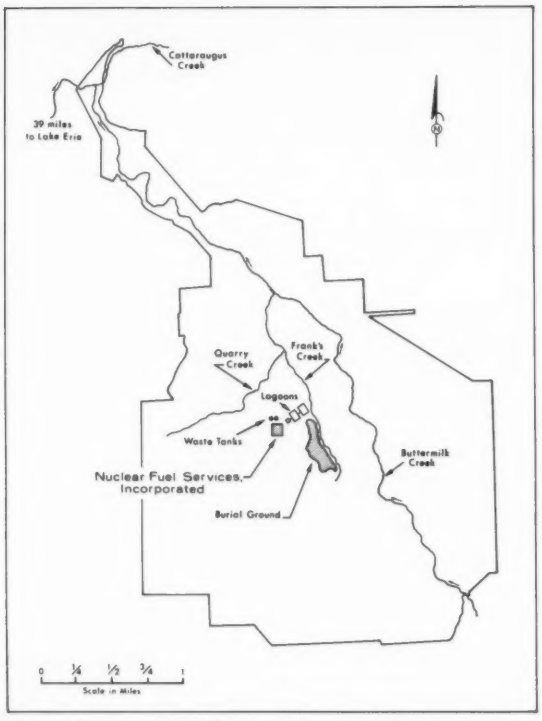

Figure 1. Site of the Western New York Nuclear Service Center

fenced and posted with "no trespassing" signs, and the NFS plant is 1,200 meters from the nearest site boundary. The NFS plant, lagoons, waste tanks, and burial grounds are enclosed inside a 10-foot-high chain-link and barbed-wire fence. The plant is equipped with a lagoon system for low-level, liquid-waste storage and discharge and a 200-foot stack for gaseous waste discharges. Wastes with high levels of radioactivity are stored in buried tanks on the site (see figure 1 for location).

The total population of the five counties in this area was 1,370,000 in 1960. Statistics on population within various radii of the plant and population density are provided in table 1. Dairying and farming are principal industries in the area.

Fuel reprocessing

The plant operation consists of separation and recovery of plutonium and unused uranium from spent fuel elements. NFS is capable of reprocessing 1 metric ton (tonne) per day of any low-

Table 1. Population in vicinity of Nuclear Fuel Services (*1*)

Radius from site	Population within radius (1960)	Population density within radius (persons/sq. mi.)
5 miles	5,765	73
10 miles	15,644	50
15 miles	39,297	56
20 miles	62,432	50
25 miles	170,573	87

enriched nuclear fuel which can be reduced to a nitric acid solution. The fuel is cooled at least 150 days before processing, and most fuel is cooled for over a year, thus permitting radioactive decay of the shorter-lived radionuclides.

The spent fuel is transported to NFS in shielded casks by rail or truck. Each cask is placed in the unloading pool, a tank of water 44-feet deep. There the casks are opened, and the fuel elements are transferred into storage canisters. After an appropriate storage time, the canisters are moved to the processing area. An underwater conveyor carries the canisters from the storage pool to the shielded Process Mechanical Cell (PMC) where the reprocessing begins as diagrammed in figure 2. Each fuel element is removed from its canister, mechanically chopped into pieces, put into baskets, and stored in the General Purpose Cell (GPC) for later chemical processing. After analysis and adjustment, the feed from the chemical processing cell is jetted to the extraction cells (figure 2), where the fission products are chemically separated from the uranium and plutonium, and the uranium and plutonium are separated from each other. The uranium and plutonium solutions are then purified, evaporated to desirable concentrations, and packaged in geometrically safe containers for storage and shipment. The fission products in the waste solution are processed as high-level liquid waste. The fuel reprocessing operation for a particular batch usually takes 30–60 days and can involve up to 60 tonnes of spent fuel.

Technical specifications

NFS is required to operate its plant in accordance with an AEC license and associated technical specifications (*2*) which establish operating limi-

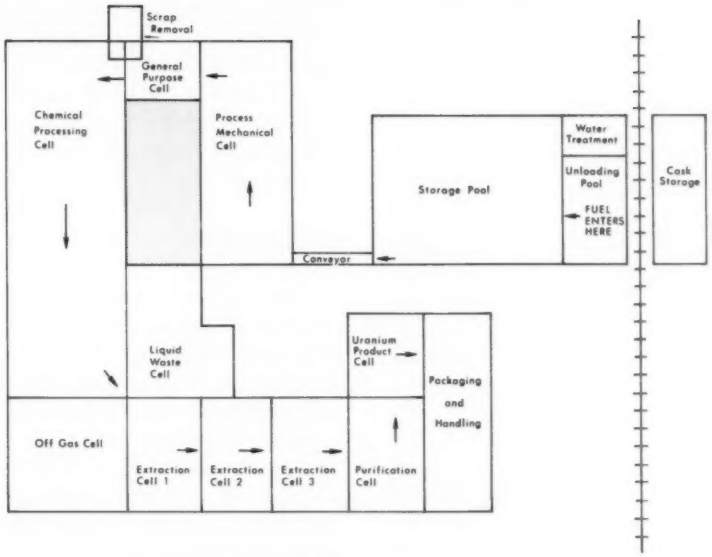

Figure 2. NFS Purex Process diagram

tations. Following are the limits in these technical specifications for gaseous waste discharges:

Krypton-85	12.6 kilocuries per day
Iodine-131	3.3 curies per year
Particulate	0.1 microcurie per second (monthly average gross alpha plus beta)

Stack sampling and continuous monitoring of stack effluent are used to confirm compliance with release limits.

Concentrations in liquid discharges are limited as follows (*2*): "Activity released to Cattaraugus Creek from all sources on the site shall not at any time result in a concentration as measured at the monitoring station in Cattaraugus Creek which exceeds twice the concentration specified in Title 10 Code of Federal Regulations Part 20; provided, however, that in any 365-consecutive-day period, the average concentration of radioactivity in Cattaraugus Creek shall not exceed that specified in Title 10 Code of Federal Regulations Part 20."

"No more than 48 combined equivalent curies of alpha and beta activity other than tritium shall be transferred to the storage lagoons during any calendar quarter."

For purposes of these limits, the point of discharge is currently defined as the point where Cattaraugus Creek leaves the WNYNSC site (figure 1).

Table 2 includes data on liquid and gaseous wastes discharges as a percentage of limit. The percentages are not proportional to gross activity for liquid wastes because the concentration limit is a function of the radionuclide content. Also, the limit is expressed as a maximum concentration, and therefore, the percentage of limit depends on the flow rate of the creek, as well as gross beta-gamma activity discharged.

Radioactive waste

There are at least six ways radioactivity could be released from NFS to the environment:

1. Leakage during shipping and handling;
2. Egress of contaminated personnel or material;
3. Gaseous particulate waste discharged from the stack;
4. Low level radioactive liquid released from lagoons to Buttermilk Creek;
5. Leakage from high level liquid waste storage

Table 2. General operational data for Nuclear Fuel Services[a]

Operational data	1966				1967				1968				1969				1970		
	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.	4th qtr.	1st qtr.	2nd qtr.	3rd qtr.
Fuel processed (tonnes)	—	52.5	46.6	15.5	1.98	27.6	39.7	51.8	36.8	45.1	51.6	3.2	28.6	37.4	33.4	21.5	13	7.6	14
High and low-level solid waste buried onsite (Ci/qtr)	—	5.9	629	111	120	5,000	13,400	850	620	450	540	1,120	2,160	13,200	2,400	1,965	.083	.057	.25
High-level liquid waste in storage tanks (megacuries of cesium-134 and -137)	—	—	—	—	—	—	—	4.1	3.5	3.6	4.3	3.9	4.0	7.1	6.3	6.6	6.9	8.5	12
Liquid waste discharged (α-β less H^3, Ci/qtr)	.012	.3	2.8	5.1	7.9	3.6	4.2	22.6	15.7	5.4	4.7	20.7	20.6	44.4	35.3	36.3	29.14	18.44	26.8
Liquid waste discharged as percent of limit[b]	—	—	—	—	16.5	13.8	21.0	11.4	9.2	5.2	12.2	12.6	18.9	12.6	40.1	30.0	19.0	8.2	21.2
Tritium discharged in liquid waste (Ci/qtr)	3.2	19.5	212	58	1,080	1,218	1,380	536	920	356	925	441	1,125	2,045	773	2,037	1,695	1,018	930
Gaseous waste discharged (Xe megacuries)	—	.002	.058	.029	.052	.076	.13	.066	.036	.035	—	—	—	—	—	—	—	—	—
Gaseous waste discharged as percent of limit	—	[c].17	[c]5.0	[c]2.5	[c]4.6	[c]6.6	[c]11.4	[c]5.7	[c]3.1	[c]3.0	[c]8.5	[d]11.0	[d]13.0	[d]44.0	[d]19.0	[d]19.0	[d]39.0	[d]44.0	[d]34.0
Particulates in gaseous waste (Ci/qtr)	—	.011	.089	.048	.053	.164	.241	.025	.432	.397	.135	.079	.094	.005	.0003	.017	.008	.073	.077
Particulate discharges from stack (percent of limit)	—	—	—	6.1	6.67	20.83	30.07	3.13	56.0	47.67	18.4	9.23	11.27	.43	.39	2.27	1.17	8.01	9.63

[a] Based on reference 3. [b] Based on limits of 3×10^{-7} μCi/ml for strontium-90, 1×10^{-6} μCi/ml for other beta emitters except tritium, and 5×10^{-6} μCi/ml for alpha emitters.
[c] Based on limit of 1.26×10^{4} Ci/day, and the average of quarterly totals discharged. [d] Maximum percent of daily limit, stated in footnote [c]. —, data not reported.

tanks to creek system; and

6. Leakage from solid waste burial grounds.

Safe procedures and adequate equipment controls have prevented environmental contamination from items 1, 2, and 5 above. General information on the radioactive waste from the plant is provided in table 2.

Stack discharges

The primary sources of contaminated gaseous wastes are the chopping and dissolution processes. The gas is then put through a chemical scrubber, dual high-efficiency filters, and iodine filters before mixing with ventilation air and discharge to the atmosphere. The stack is 200 feet high with a nominal discharge rate of 50,000 cubic feet per minute. Krypton-85 is considered to be the most significant gaseous waste radionuclide. Due to the short half-life of iodine-131 (8 days) and the relatively long storage time before processing, it is released in quantities less than 1 percent of the maximum permissible amount. A small amount of iodine-129 with a half life of 1.7×10^{7} years is released. Insufficient data are available to date to evaluate the significance of introducing a small amount of this long-lived isotope into the iodine pool of the biosphere. The EPA Radiation Office published a study entitled "Public Health Aspects of Iodine-129 from the Nuclear Power Industry" (*4*) which briefly discussed iodine-129 in the envirionment around NFS. This study concluded that there is an apparent local buildup of iodine-129 taking place around NFS. However, there was insufficient information relative to pathways to relate concentrations to dose.

Low-level liquid wastes

The primary source of liquid waste with a low level of radioactivity is the condensate from the series of evaporators which are used to concentrate high-level liquid waste and to recover the acid. Low-level waste is generally considered to have gross alpha-plus-beta activity between 3×10^{-7} and 5×10^{-3} μCi/ml. Low-level wastes may be further decontaminated by evaporation and condensation prior to storage in lagoons, which provide additional decontamination through settling. Liquids in the lagoons are discharged at a con-

trolled rate into Frank's Creek, which flows through the site to Buttermilk Creek and then to Cattaraugus Creek, which flows into Lake Erie.

The effluent discharge rate of the plant is about 50,000 gallons per day. The lagoon network has two 22,000-gallon interceptors, a 300,000-gallon lagoon, and two 2.3 million-gallon lagoons. The average holdup period is about 1 month, and the maximum holdup capacity is 100 days.

Table 3 lists the principal radionuclides contributed to the environment via liquid discharges from NFS. The percent of limit column refers to limits for concentrations in water and does not consider the possibility of radionuclide concentration through environmental media. Strontium-90 and cesium-137 are the greatest contributors to population dose when all exposure pathways are considered (*5*).

Figure 3 includes plots of liquid waste discharges and fuel reprocessed as functions of time. This figure indicates a general increase in low-level liquid waste discharged, with a decrease in fuel processed. NFS attributes this increase to the processing of higher exposure reactor fuel in 1969 (*6*), but the Northeastern Radiological Health Laboratory suggests (*7*) that waste management policy is also a factor. NFS modified the waste management policy during the last quarter of 1970 to reduce significantly the discharge of gross beta-gamma radioactivity (excluding tritium). The modified policy included the evaluations of the contribution of individual sources of radioactive liquid being discharged to the low-level liquid holdup system and reduction or elimination of these sources wherever possible and the limiting of gross beta concentrations released to Cattaraugus Creek to 150 pCi/liter.[2]

Table 3. Radionuclides contributed to the environment in liquid effluent from NFS[a]

Radionuclide	Quantity discharged May to October 1969 (curies)	Percent of 10CFR20[b] concentration limit in Cattaraugus Creek water	
		June 17, 1969	November 4, 1969
Tritium	1,700	1.1	0.10
Ruthenium-106	52	5.2	.75
Cesium-137	8.0	.008	.15
Cesium-134	2.0	<1	<1
Strontium-90	8.3	17	23
Cerium-144	.16	<1	<1
Promethium-147	.092	<1	<1
Zirconium-95	.0046	<1	<1
Cobalt-60	.20	<1	<1
Antimony-125	.59	<1	<1
Manganese-54	.0027	<1	<1
Plutonium	.0018	<1	<1
Uranium	.032	<1	<1
Gross alpha	.048		

[a] Reference 7.
[b] Code of Federal Regulations, Title 10, Part 20, Appendix B, table D.

High-level liquid waste

High-level radioactive liquid waste comes from the extraction processes. This waste is concentrated and stored underground on the site (figure 1) in steel tanks which are in saucers enclosed by concrete vaults. The tanks are monitored for leakage both inside and outside the concrete, so that there is little possibility of a leak of radioactivity to the environment from this source. Even in the unlikely event that a leak should develop, the highly impermeable soil would prevent the spread of contamination.

Figure 3 includes a plot of cesium-134 plus cesium-137 in high-level liquid waste in storage as a function of time. It is noted that there is sometimes a net decrease in the amount of activity in storage from quarter to quarter, even though new waste is constantly being added to the tanks. This fluctuation is probably due to the difficulty in obtaining a representative sample of the wastes, coupled with variations in the total volume due to boiloff of water from the tank.[3]

Solid waste

Solid radioactive waste consists of discarded claddings, equipment, and other materials used in operations. It is buried on the site (figure 1) in impervious, silty till with good ion-exchange properties.

Environmental considerations

There are many farms and dairies in the area of NFS. Major crops are beans, corn, oats, and wheat. A few dairy herds have access to Cattaraugus Creek. The creek has been used on a few occasions in the past for irrigation. It is not a public water supply, but it is used for recreational

[2] Personal communication to Mr. Robert N. Miller (NFS) from Mr. Marvin M. Mann (AEC) dated December 4, 1970.

[3] Personal communication to Mr. M. S. Terpilak of the EPA Radiation Office from Dr. E. D. North of Nuclear Fuel Services, dated March 12, 1971.

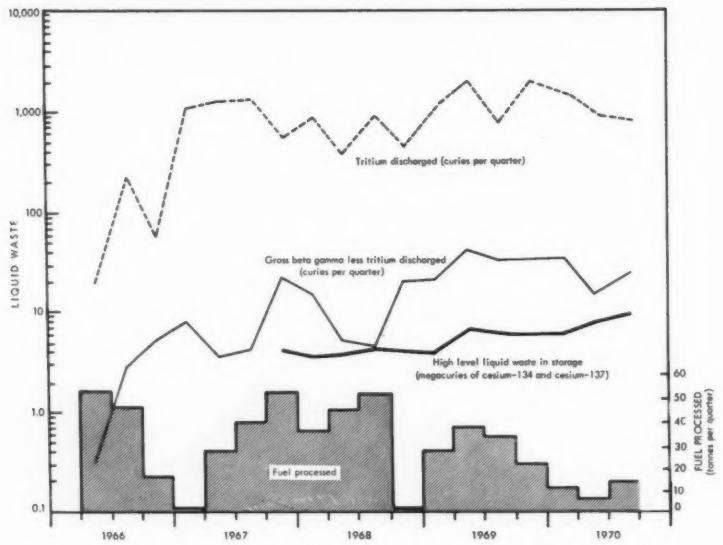

Figure 3. NFS liquid waste and amount of fuel processed

purposes, including fishing, swimming, picnicking, and boating. Thus, several potential indirect population exposure pathways exist in addition to direct exposure pathways through air, surface water, and external exposure.

There are programs of continuous monitoring at various locations around NFS. Measurements are taken on samples of water supplies, surface water, air, direct radiation, milk, silt, soil, vegetation, fish, and other wildlife. NFS is required by the AEC to continuously monitor gaseous and liquid waste discharges. A recent change (# 13) to the NFS technical specifications requires more environmental surveillance, including identification of exposure pathways. It also requires more detail in facility reports of waste discharges and environmental measurements than was previously required.

New York State conducts routine and special environmental monitoring around NFS (*8*, *9*). The AEC is conducting a special independent program of measurements around NFS (*10*), which started in 1967 and has continued to the present. Table 4 provides a summary of the environmental surveillance being conducted around NFS. It includes type and number of samples, as well as types of analyses. The summary of the NFS environmental surveillance refers to the surveillance done prior to change # 13 to the technical specifications. This change requires the following environmental surveillance not previously included:

1. Direct radiation measurements at 3 locations along the site perimeter;
2. Tritium concentration in precipitation at 3 locations along the site perimeter;
3. Special milk samples to be analyzed for iodine-131 as a function of release quantity and meteorological conditions at the time of release;
4. Two semiannual milk samples to be analyzed for iodine-129, strontium-90, cesium-134, and cesium-137;
5. Fish samples during second and third quarter of each year to be analyzed for cesium-134, cesium-137, and strontium-90 in flesh plus strontium-90 in the skeleton with the median and geometric deviations of the measurements; and
6. An annual deer sample analyzed for cesium-134, cesium-137, and strontium-90 in the flesh and strontium-90 and strontium-89 in the skeleton.

Table 4. Summary of environmental surveillance programs around Nuclear Fuel Services[a]

	Media sampled									
	Air particulates	Direct radiation	Surface water	Surface water supplies	Silt	Fish	Milk	Vegetation	Soil	Deer
Nuclear Fuel Services:[a]										
Number of locations	4	—	6	1	1	1	1	1	1	—
Frequency	1 daily, 3 weekly	—	Monthly	Monthly	Monthly	Semi-annually	Weekly	Biweekly	Monthly	—
Type of analysis	Gross alpha, gross beta	—	Gross α, ^{131}I, gross β, ^{3}H, ^{90}Sr	Gross α, gross β, ^{90}Sr, ^{3}H	Gross α, ^{90}Sr, gross β	Gross α, ^{90}Sr, gross β	Gross β, ^{131}I	Gross α, ^{90}Sr, gross β	Gross α, ^{90}Sr, gross β	—
New York State:										
Number of locations	5	30	9	—	4	5	13	—	—	4 or 5
Frequency	Weekly	Annually	1 daily, 4 weekly, 4 monthly	—	Semi-annually	Semi-annually	1 farm/day	As necessary	As necessary	Semi-annually
Type of analysis	Gross β	γ	Gross β, ^{89}Sr, ^{90}Sr, γ, ^{3}H, Pu, U	—	γ, ^{90}Sr	γ, ^{90}Sr	γ, ^{3}H, ^{90}Sr, ^{131}I	—	—	γ, ^{90}Sr, ^{129}I, Pu in lung
Atomic Energy Commission:										
Number of locations	4	20	7	5	4	2	2	3	2	—
Frequency	Weekly	Monthly	Weekly	Monthly	Quarterly	Semi-annually	Monthly	Bimonthly	Bimonthly	Split samples with States
Type of analysis	Gross α, gross β, γ	Gross γ	Gross α, gross β, ^{90}Sr, ^{3}H, γ	Gross α, gross β, γ, ^{3}H, ^{90}Sr	Gross α, gross β, γ	Gross α, gross β, γ	Gross β, ^{131}I, ^{90}Sr, ^{137}Cs	Gross α, gross β-γ	Gross α, gross β-γ	—

[a] Does not reflect changes instituted as a result of change #13 to the NFS technical specifications.

The U.S. Public Health Service has conducted special environmental studies around NFS (*5*, *7*, *11*). These studies indicate that there are no immediate hazards to public health due to discharges from NFS, but they call attention to certain critical pathways of exposure to man which should be carefully monitored. The most important pathways for public exposure in the vicinity of the site appear to be through flesh from deer and flesh from fish in the area of NFS. The most significant radionuclides involved in these pathways are: strontium-90, cesium-137, cesium-134, and ruthenium-106. Krypton-85 and tritium may become important from the standpoint of worldwide buildup but not necessarily for local population exposure.

Conclusions

The Nuclear Fuel Services fuel reprocessing plant has been in operation since 1966 and has provided valuable experience in waste management problems related to this type of facility. The large quantities of radioactivity which must be controlled at a nuclear fuel reprocessing plant virtually eliminate discharge-and-dilution as a satisfactory method of disposing of radionuclides which concentrate through environmental media. Radionuclides such as strontium-90, ruthenium-106, cesium-137, cesium-134, cobalt-60, tritium, and krypton-85 have been found in environmental media around NFS. These indicate that pathways to the public do exist as a result of operation of the facility. However, studies to date have indicated that typical population doses in the vicinity of NFS are not significantly different from doses received in other portions of the State (*5*).

No particular time correlation exists between discharges of liquid waste from NFS and the amount of fuel reprocessed. This is to be expected due to the long holdup period in the lagoons and because quantities of radionuclides discharged depend primarily on the nature of the fuel processed and waste management practices. One might expect that, as experience is gained in waste processing techniques, the amount of radioactivity discharged relative to the amount of fuel processed would be lower. However, this has not been the

case. Plots of the data indicate that this ratio actually has been increasing. Increased discharges and associated environmental measurements by New York State, PHS, and the AEC have led to increased surveillance around NFS.

NFS is presently installing additional equipment in order to reduce releases of radioactivity in low-level wastes. This equipment is designed to remove cesium and strontium from liquid wastes. These radionuclides are the greatest contributors to population dose from NFS discharges. The installation of this equipment is a step toward maintaining discharges as low as practical in keeping with recent amendments to Code of Federal Regulations, Title 10, Parts 20 and 50.

Acknowledgement

Appreciation is expressed to Mr. Thomas L. Robinson of the Division of Surveillance and Inspection for assistance in data compilation for this report.

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Characterization and Certification of Health Physics Technicians[1]

Ronald L. Kathren[2]

Personal, educational, and occupational history was obtained from a survey of more than 300 health physics technicians. The "average" technician is a 36-year-old married male with about 10 years of experience in the nuclear field. About two-thirds are veterans. Half of the group have completed two or more years of college, and most received specific training in radiological health on the job. Because of the diversity of educational and occupational backgrounds, a voluntary certification program is proposed, with certification requiring the passing of a written examination in addition to several years of experience and other requirements.

Among the newer members of the public health team are health physics technicians, a heterogeneous group concerned with protection against ionizing radiation. The composition of this group is the object of a study by a joint subcommittee of the Columbia Chapter and the Education and Training Committee of the Health Physics Society.[3] To date, this subcommittee has surveyed by mail questionnaire more than 300 nonprofessional personnel in the health physics–radiological health area, obtaining data on personal, educational, and occupational history.

The questionnaires were distributed through the 30 chapters of the Health Physics Society. This method of distribution, while almost certain to provide biases because of the characteristics of the membership of the chapters as well as the geographical distribution, nonetheless resulted in a very high percentage return (approximately 70 percent) of questionnaires and a sufficiently large sample (310 respondents) to permit some inferences to be drawn from the results. Returns were received from all over the United States with about an equal number from either side of the Mississippi River.

Although the questionnaire was designed to preserve the anonymity of the respondent and therefore did not provide the means of tying an individual to a specific job, it was nonetheless possible to get a qualitative feeling for the types of respondents. A significant fraction—perhaps on the order of 50 to 60 percent—were monitors associated with Atomic Energy Commission (AEC) laboratories or test sites. Employees of power reactors accounted for an estimated 5 to 10 percent of the total, and those employed by governmental agencies other than AEC (primarily Public Health Service (PHS)) probably accounted for a similar number. The remainder included those working in close support of the medical profession and employees of universities and industry in general. The distribution of respondents is probably similar to the actual distribution of technicians in the radiation protection field.

Personal and family history

As a group, health physics technicians are youthful males, having a median age of 37 and a mean age of 36, not too unexpected a finding when one considers the relative age of the nuclear industry and the demographic pattern of the past several decades. The age distribution has the positive skewness expected as the result of the minimum age at which employment is generally begun.

Nearly half of the respondents were born in the relatively sparsely populated areas of the so-called

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plains, Rocky Mountain, and, in part, southwestern States. Three of the States in this area—Idaho, Colorado, and New Mexico—alone contributed about 20 percent of the total, with Pennsylvania and New York contributing about 13 percent. Surprisingly, California, with its multiplicity of nuclear sites and proximity to the Nevada Test Site, was the birthplace of only about 3 percent of the respondents. Less than 1 percent were foreign-born. Ninety-four percent of the respondents were male, and 87 percent were married, with less than 4 percent, divorced or separated.

Family history data showed that the technicians typically came from a "white collar" family with 3.8 children, not appreciably different from the average U.S. family size for 1920–1950, when most were born (*1*). About 14 percent reported that their fathers were farmers, a number only slightly lower than the approximately 17 percent of the experienced labor force in farming pursuits in 1940 (*2*). (The year 1940 was used as a comparison year, since data are readily available (*3*) and the median health physics technician would have been 7 years old.) However, a relatively large proportion of the technicians' fathers were white-collar workers—31 percent as contrasted with 17 percent of the labor force in 1940. The proportions of professionals and skilled workers were comparable to those in the 1940 labor force, but the technicians reported only 7 percent of their fathers in unskilled or service occupations as compared with approximately 38 percent of the 1940 work force.

Approximately two-thirds of the respondents are serving or had served in the military, but only about one in three of these were veterans, indicating a reserve commitment and underscoring again the youthfulness of the group. When looking at the breakdown of individual services, as shown in table 1, there appears to be a somewhat greater proportion of Navy men than would be expected in a more random sample of occupational groups, and it may well be that many of the health physics technicians learned of the nuclear field through the very active Navy programs.

Table 1. Military background of health physics technicians

Branch of service	Percent
Army	26
Air Force	15
Navy	18
Marines	3
Other	2
No service	35
Rank in service	
Commissioned	14
Master Sgt., CPO, WO	14
Other enlisted	72

Educational background

The educational level of the 310 respondents is shown in figure 1. For comparison, the distribution of the father's educational level is also shown. Of significance is the high proportion of individuals with some formal college level work. The median educational level was 14 years (2 years of college).

In addition to the indicated categories of formal education, about two-fifths of the technicians had received additional formal education; nine had attended AEC-sponsored schools or courses; 28 had attended military schools; 31, technical schools; and 53 had taken miscellaneous college courses, PHS training courses, etc.

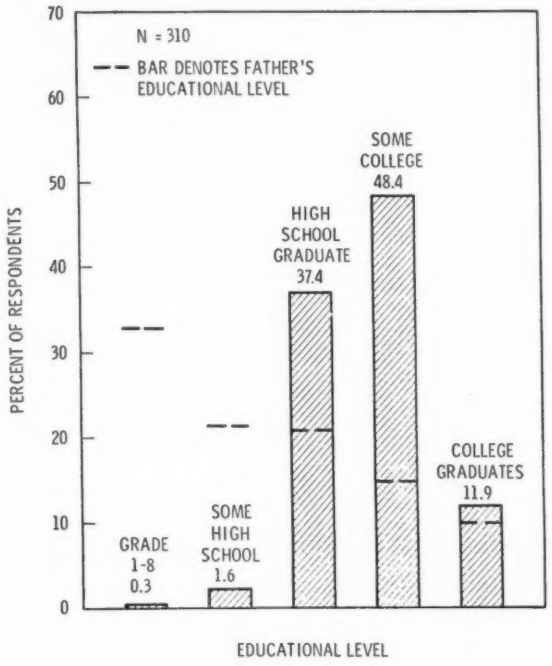

Figure 1. Educational levels of respondents

With respect to specific technician training, an overwhelming majority (75 percent) received their training on the job. Approximately equal numbers (12 percent) cited academic or a combination of academic and on-the-job training as their job preparation. Surprisingly, a similar fraction (75 percent thought their on-the-job training was adequate, even though it may have been only a few hours in duration and may have been their only orientation in radiological health. Only 18 percent—less than 1 in 5—felt that their preparation for their present jobs was inadequate.

Occupational history

The average respondent had nearly 11 years of experience in the nuclear field, and virtually all of that in the radiation protection area. However, the few with more than 20 years of experience tend to artificially inflate the mean. Examination of the distribution in figure 2 shows that most technicians—about two-thirds—have less than 10 years of experience. In part, this is a reflection of the youthfulness of the group, but since most of the technicians have been in the job market for 15 years or more, it indicates that, in general, they did not start in the nuclear field. In response to why they entered the nuclear field, 30 percent indicated interest; 14 percent, money; 11 percent, security; and most others gave reasons relating to interest, security, and future; statements like "a growing field" were not uncommon.

Generally, the health physics technician appears to be job stable. He has been on his present job an average of 5.9 years and has changed employers an average of 0.41 times. Fewer than 10 percent have changed employers more than twice since entering the nuclear field. Of those who have changed, pay was the overwhelmingly decisive factor, with layoffs and lack of opportunity for advancement in second place, far down the list. Salary was a factor in at least 48 of the 121 job changes.

Response to specific questions regarding job and employer revealed an interesting, mixed response, as summarized in table 2. In the main, the health physics technicians are an occupationally satisfied group, but one which does not think it is used to the full extent of its capabilities, nor paid adequately. Such a pattern could probably describe most professional groups in the scientific and technical disciplines.

Of especial interest and significance is how the respondents categorized themselves occupationally. About half felt that their jobs could be

Table 2. Job satisfaction factors of health physics technicians

Factor	Percent
Overall satisfaction	73
Promoted on job	54
Fully challenged	27
Adequate responsibility delegated	81
Advancement hampered by job class	56
Adequate pay	39
Acceptable location	59

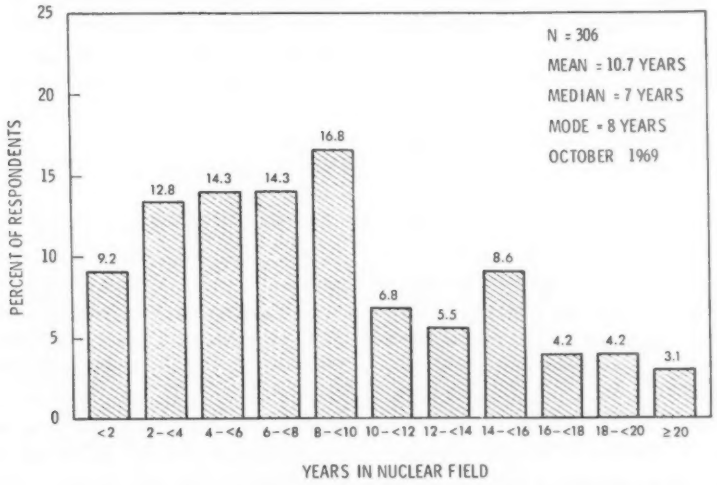

Figure 2. Health Physics technicians' experience in the field

described as "health physics technician," 35 percent as "nuclear technician," and 29 percent as "monitor." About 8 percent thought of themselves as "radiation technician," and a smattering of other responses were received. Several individuals listed more than one job title, indicative perhaps, of the multitude of titles used in industry to describe essentially the same job. A single job title would probably be beneficial, and would help with group identification. Health physics technician appears to be the most satisfactory title for, in addition to being the choice of the group itself, it identifies with a recognized and established professional group.

Certification

By a ratio of more than eight to one, the technicians felt that certification would be of benefit to them, and this alone may be adequate reason for instituting a certification program. However, there are other and perhaps more compelling reasons for a certification program. Perhaps the most obvious of these is the establishment of a baseline level of competence for a group that daily has responsibility for human life and well being and thousands of dollars worth of property. In this way, certification serves as a useful quality control device. One needs only to speculate on the consequences of an error directly attributable to incompetence: the release of curie quantities of radioactivity to the environment, overexposure that could be disabling or even fatal to a worker, a criticality accident with loss of life and tremendous economic ramifications.

Review of the educational and employment history of those participating in the survey underscores the need for a formal certification program. The fact that 82 percent felt their specific radiological health training was adequate, irrespective of duration coupled with three of four individuals receiving this training "on-the-job," places a very heavy reliance on the adequacy of the employer's training program. And since technicians are job stable and have relatively little intercourse with other technicians or professionals from other companies, the question of breadth of knowledge and scope may be raised. Such questions can easily be resolved by a sound certification program.

Certainly there is a precedent for certification of technicians, as exemplified by the certification programs for x-ray technicians and engineering technicians. In the case of both of these groups, uncertified persons can still work in the field, but certification is an important goal that has helped to upgrade both personnel and quality of work.

A sound certification program could be established along the lines of certification already available for other technician groups, such as x-ray technicians and engineering technicians. Logically, administration of the program should fall to the American Board of Health Physics, which could coordinate both the professional and technician certification programs. An independent or semi-independent subsidiary board, composed of both technicians and health physicists, could serve the program.

The basic requirements for certification as a health physics technician have already been proposed (*3*) and are reiterated below. These broad requirements appear reasonable and consistent with industrial and governmental job classifications and goals.

1. Course work beyond high school equivalent to no less than 60 semester hours of junior or technical college level course-work, with at least 36 semester hours in the sciences, engineering, and radiation technology;
2. A minimum of 2 years of experience in radiation monitoring or other health physics technician functions performed in a recognized program under the direct supervision of a certified health physicist. Additional experience can be substituted for the course work described in (1) above on the basis of 1 year for each 15 semester hours;
3. A minimum age of 21 years and good moral character;
4. Recommendation by a certified health physicist or two certified health physics technicians; and
5. Passing of a written examination, prepared and administered by the certifying board.

There would be no 'grandfather' clause; each would take the written examination to demonstrate his ability. Furthermore, it might be well to close the certification process to those employed as professional health physicists, and those to whom radiation protection work is secondary.

Beneficiaries of a certification program would be many. Potential employers would benefit from the preevaluation of prospective employees that such a certification program would accomplish. Knowledge that monitors, for example, have evidenced a minimum level of competence is both economically and psychologically reassuring. Management knows too well the price of incompetence.

The benefits of certification to the recipient are well known. Recognition for technical accomplishments, establishment of an identifiable group, and increased salary, job security, and status are but a few. The self-satisfaction that accompanies a meaningful certification provides a psychological lift and increased self-confidence.

The major benefactor, however, would be the public. Certification of health physics technicians is decidedly in the public interest if only as a quality control measure, but in addition provides a psychological service and has public relations value.

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SECTION I. MILK AND FOOD

Milk Surveillance, February 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State Health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of meta-

Figure 1. Milk sampling networks in the Western Hemisphere

bolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2-standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*), and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration	Number of laboratories in each category			
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium-89: High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that, for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥ 50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥ 20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥ 100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and in parentheses, the number of samples analyzed in that month. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, iodine-131, and cesium-137 for February 1971 and the 12-month period, March 1970

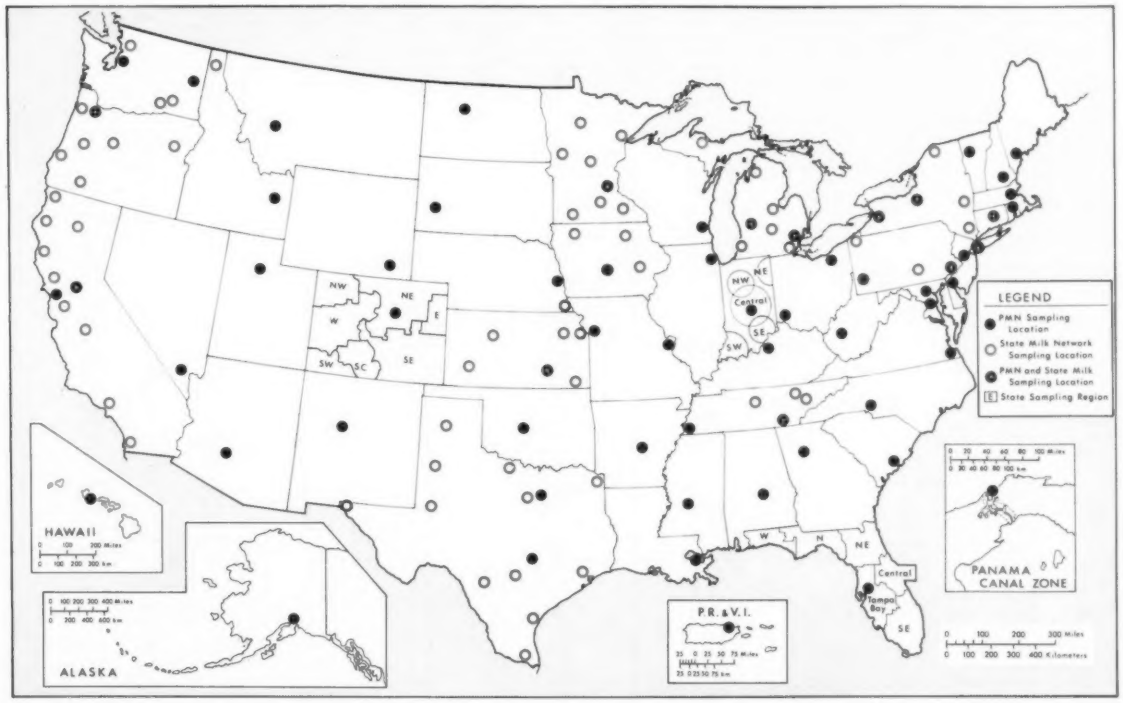

Figure 2. State and PMN milk sampling stations in the United States

Table 2. Concentrations of radionuclides in milk for February 1971 and 12-month period, March 1970 through February 1971

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	NA	6	0	0	16	9
Alaska:	Palmer[c]	P	NS	6	NS	0	NS	10
Ariz:	Phoenix[c]	P	NA	1	0	0	0	0
Ark:	Little Rock[c]	P	12	13	0	0	11	13
Calif:	Sacramento[c]	P	NA	2	0	0	0	0
	San Francisco[c]	P	NA	3	0	0	0	0
	Del Norte	P	12	17	0	0	7	13
	Fresno	P	6	2	0	0	0	1
	Humboldt	P	2	5	0	0	0	5
	Los Angeles	P	2	2	0	0	0	0
	Mendocino	P	3	3	0	0	0	2
	Sacramento	P	2	3	0	0	0	1
	San Diego	P	1	2	0	0	0	0
	Santa Clara	P	1	2	0	0	0	1
	Shasta	P	3	3	0	0	0	2
	Sonoma	P	4	3	0	0	0	1
Colo:	Denver[c]	P	NA	5	0	0	0	1
	West	R	(d)		0	1	0	4
	Northeast	R	(d)		0	0	0	0
	East	R	(d)		NS	0	NS	0
	Southeast	R	(d)		0	0	0	0
	South Central	R	(d)		NS		NS	
	Southwest	R	(d)		0	0	0	7
	Northwest	R	(d)		0	5	0	0
Conn:	Hartford[c]	P	NA	8	0	0	0	11
	Central	P	NS		NS		NS	
Del:	Wilmington[c]	P	NA	9	0	0	11	8
D.C:	Washington[c]	P	NA	7	0	0	13	7
Fla:	Tampa[c]	P	6	5	0	0	48	51
	West	R	12	9	0	0	12	16
	North	R	14	10	0	0	30	26
	Northeast	R	7	6	0	0	15	38
	Central	R	6	6	0	0	46	49
	Tampa Bay area	R	7	6	0	0	46	50
	Southeast	R	7	8	0	0	74	78
Ga:	Atlanta[c]	P	NA	11	0	0	17	14
Hawaii:	Honolulu[c]	P	0	2	0	0	0	0
Idaho:	Idaho Falls[c]	P	3	5	0	0	0	7
Ill:	Chicago[c]	P	6	7	0	0	13	10
Ind:	Indianapolis[c]	P	NA	8	0	0	13	7
	Northeast	P	8	9	0	5	10	10
	Southeast	P	8	10	0	0	10	12
	Central	P	10	11	0	0	15	12
	Southwest	P	9	11	0	0	10	12
	Northwest	P	10	12	0	0	15	10
Iowa:	Des Moines[c]	P	NA	7	0	0	0	3
	Iowa City	P	4	7	0 (2)	0	9 (2)	15
	Des Moines	P	5	8	0 (4)	0	13 (4)	10
	Spencer	P	3	5	0	0	0	8
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	NA	8	0	0	0	3
	Coffeyville	P	12	9	0	2	10	3
	Dodge City	P	7	7	0	2	0	1
	Falls City	R	NS	14	NS	3	NS	6
	Hays	P	14	13	0	2	12	2
	Kansas City	P	9	8	15	1	25	8
	Topeka	P	14	11	0	2	0	6
	Wichita	P	10	12	0	0	13	3
Ky:	Louisville[c]	P	NA	9	0	0	0	4
La:	New Orleans[c]	P	10	14	0	0	13	20
Maine:	Portland[c]	P	NA	10	0	0	17	21
Md:	Baltimore[c]	P	NA	8	0	0	0	7
Mass:	Boston[c]	P	8	10	0	0	16	21
Mich:	Detroit[c]	P	NA	8	0	0	13	10
	Grand Rapids[c]	P	NA	9	0	0	14	13
	Bay City	P	NA	7	•0	•0	16	11
	Charlevoix	P	9	12	•0 (2)	•1	15 (2)	15
	Detroit	P	NA	8	•0	•0	0	8
	Grand Rapids	P	9	9	•0	•0	13	8
	Lansing	P	8	9	•0 (2)	•0	14 (2)	14
	Marquette	P	10	13	•0 (2)	•0	20 (2)	23
	Monroe	P	6	6	•0 (2)	•0	6 (2)	3
	South Haven	R	8	8	•0 (4)	•0	4 (4)	6
Minn:	Minneapolis[c]	P	NA	10	0	0	11	11
	Bemidji	P	11	8	0	0	21	20
	Mankato	P	17	14	0	0	20	27
	Rochester	P	6	5	0	0	0	13
	Duluth	P	16	12	0	0	21	34
	Worthington	P	6	4	0	0	0	0
	Minneapolis	P	12	10	0	0	16	16
	Fergus Falls	P	8	6	0	0	13	12
	Little Falls	P	5	4	0	0	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1971 and 12-month period, March 1970 through February 1971—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES: Continued							
Miss: Jackson[c]	P	NA	12	0	0	0	10
Mo: Kansas City[c]	P	NA	8	0	0	14	3
St. Louis[c]	P	NA	8	0	0	0	4
Mont: Helena[c]	P	NA	5	0	0	16	9
Nebr: Omaha[c]	P	NA	5	0	0	0	1
Nev: Las Vegas[c]	P	NA	3	0	0	0	0
N.H: Manchester[c]	P	NA	9	0	0	18	20
N.J: Trenton[c]	P	NA	7	0	0	0	10
N.Mex: Albuquerque[c]	P	NA	3	0	0	0	0
N.Y: Buffalo[c]	P	6	7	0	0	15	11
New York City[c]	P	NA	10	0	0	12	17
Syracuse[c]	P	NA	7	0	0	16	9
Albany	P	8	7	0 (4)	0	26 (4)	*0
Massena	P	5	7	0 (2)	0	30 (2)	25
Newburg	P	17	8	0 (2)	0	*0 (2)	*0
New York City	P	13	9	0	0	21	*0
Syracuse	P	3	4	0 (2)	0	*0 (2)	*0
N.C: Charlotte[c]	P	NA	11	0	0	0	12
N.Dak: Minot[c]	P	NA	9	0	0	12	11
Ohio: Cincinnati[c]	P	NA	7	0	0	0	4
Cleveland[c]	P	NA	9	0	0	14	12
Okla: Oklahoma City[c]	P	NA	7	0	0	11	6
Oreg: Portland[c]	P	3	5	0	0	0	4
Baker	P	NS	4	*0	*0	*0	6
Coos Bay	P	NS	6	*0	*0	*0	13
Eugene	P	NS	2	*0	*0	*0	1
Medford	P	NS	3	*0	*0	*0	8
Portland composite	P	NS	5	*0	*0	*0	6
Portland local	P	NS	5	*0	*0	*0	6
Redmond	P	NS	4	*0	*0	*0	*0
Tillamook	R	NS	8	*0	*0	19	18
Pa: Philadelphia[c]	P	NA	9	0	0	0	7
Pittsburgh[c]	P	NA	11	0	0	18	15
Dauphin	P	3	7	0	1	17	10
Erie	P	3	10	0	1	24	24
Philadelphia	P	13	8	0	0	24	15
Pittsburgh	P	0	12	11	1	15	20
R.I: Providence[c]	P	NA	9	0	0	16	17
S.C: Charleston[c]	P	9	10	0	1	11	17
S.Dak: Rapid City[c]	P	NA	7	0	0	0	4
Tenn: Chattanooga[c]	P	NA	10	0	0	0	8
Memphis[c]	P	NA	9	0	0	11	8
Chattanooga	P	8	9	0	0	17	15
Clinton	P	9	11	0	0	21	15
Knoxville	P	6	7	0	0	15	13
Nashville	P	6	6	0	0	13	10
Fayetteville	P	9	11	0	0	11	14
Tex: Austin[c]	P	NA	3	0	0	0	2
Dallas[c]	P	NA	7	0	0	0	6
Amarillo	R	NS	4	NA	NA	NS	5
Corpus Christi	R	3	3	NA	NA	0	0
El Paso	R	2	3	NA	NA	0	2
Fort Worth	R	NS	5	NA	NA	NS	0
Harlingen	R	NS	2	NA	NA	NS	0
Houston	R	NS	6	NA	NA	NS	14
Lubbock	R	2	3	NA	NA	0	0
Midland	R	NS	2	NA	NA	NS	0
San Antonio	R	NS	4	NA	NA	NS	0
Texarkana	R	NS	8	NA	NA	NS	0
Tyler	R	10	13	NA	NA	10	17
Uvalde	R	NS	2	NA	NA	NS	0
Wichita Falls	R	5	8	NA	NA	0	0
Utah: Salt Lake City[c]	P	5	4	0	0	23	11
Vt: Burlington[c]	P	NA	8	0	0	13	15
Va: Norfolk[c]	P	NA	9	0	0	14	9
Wash: Seattle[c]	P	NA	6	0	0	0	3
Spokane[c]	P	NA	5	0	0	0	2
Benton County	R	NS	0	NS	0	NS	2
Franklin County	R	3	3	0	0	0	3
Sandpoint, Idaho	R	8	11	0	0	12	22
Skagit County	R	5	6	0	0	12	11
W.Va: Charleston[c]	P	NA	8	0	0	0	5
Wisc: Milwaukee[c]	P	NA	6	0	0	14	12
Wyo: Laramie[c]	P	NA	5	0	0	0	1
CANADA:							
Alberta: Calgary	P	(d)		(d)		29	18
Edmonton	P	(d)		(d)		23	20
British Columbia: Vancouver	P	(d)		(d)		16	24

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1971 and 12-month period, March 1970 through February 1971—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)					
		Strontium-90		Iodine-131		Cesium-137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA: Continued							
Manitoba:							
Winnipeg	P	(d)		(d)		18	24
New Brunswick:							
Fredericton	P	(d)		(d)		22	22
Newfoundland:							
St. John's	P	(d)		(d)		18	34
Nova Scotia:							
Halifax	P	(d)		(d)		8	22
Ontario: Ft. William	P	(d)		(d)		15	15
Ottawa	P	(d)		(d)		33	33
Sault Ste. Marie	P	(d)		(d)		24	25
Toronto	P	(d)		(d)		14	10
Windsor	P	(d)		(d)		13	11
Quebec: Montreal	P	(d)		(d)		23	18
Quebec	P	(d)		(d)		30	28
Saskatchewan:							
Regina	P	(d)		(d)		16	14
Saskatoon	P	(d)		(d)		17	16
CENTRAL AND SOUTH AMERICA:							
Colombia:							
Bogota	P	NS	0	NS	0	NS	0
Chile: Santiago	P	0	0	0	0	0	0
Ecuador: Guayaquil	P	NS	0	NS	0	NS	0
Jamaica: Mandeville	P	NS	6	NS	0	NS	84
Venezuela:							
Caracas	P	0	1	0	0	0	0
Canal Zone:							
Cristobal[e]	P	NA	1	0	0	12	10
Puerto Rico:							
San Juan[e]	P	NA	4	0	0	12	7
PMN average[f]		6	7	0	0	8	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one annlysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [e].
NA, no analysis.
NS, no sample collected.

through February 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for February 1971 were below the respective practical reporting levels. The following station average reflects a sample in which strontium-89 was detected: Idaho Falls, Idaho, (PMN), 6 pCi/liter; New Orleans, La., (PMN), 7 pCi/liter.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower guide levels established by the Federal Radiation Council, levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range 1 (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 17 pCi/liter in the United States for the month of February 1971, and the highest 12-month average was 17 pCi/liter (Del Norte, Calif.) representing 8.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 74 pCi/liter in the United States for February 1971, and the highest 12-month average was 78 pCi/liter (South-

east Florida), representing 2.2 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level, with the exception of Kansas City, Kans., (State), 15 pCi/liter, and Pittsburgh, Pa., (State), 11 pCi/liter.

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Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Nuclear Engieeering
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Service

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Radiostrontium in Milk, January-December 1969

Health and Safety Laboratory
U.S. Atomic Energy Commission

In 1954, the Health and Safety Laboratory began monitoring strontium-90 in liquid whole milk in New York to estimate the dietary contribution from ingestion of radiostrontium in milk. Subsequently, powdered milk monitoring was initiated at Perry, N.Y. (1954), and at Mandan, N. Dak. (1955). Liquid whole milk monitoring was started in Honolulu, Hawaii, in August 1959. Sampling was terminated at Mandan, N. Dak., and Honolulu, Hawaii, at the end of June 1965.

The New York City sample is a monthly composite of pasteurized milk purchased daily in quart containers at retail stores. Five large dairies are represented in the sample. The Perry samples are monthly composites of powdered whole milk for human consumption collected weekly in 5-pound lots from plants in the city. The strontium-90-to-calcium ratios in whole milk are presented in table 1.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1968	October 1969

Table 1. Strontium-90 to calcium ratios in milk, January–December 1969[a]

Sampling location	Strontium-90 to calcium ratio (pCi ^{90}Sr/g Ca)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
New York, N.Y. (liquid whole milk)	9.3	7.3	6.7	6.7	8.3	10.8	13.1	10.4	10.4	8.0	8.5	8.5
Perry, N.Y. (powdered whole milk)	8.0	7.4	7.2	6.2	6.4	6.4	8.8	8.6	9.4	7.2	7.2	7.9

[a] Data summarized from "Fallout Program Quarterly Summary Report," HASL-237, available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	January–June 1970	November 1970
Carbon-14 in Total Diet and Milk	July–December 1970	May 1971
Connecticut Standard Diet	July–December 1969	December 1970
Institutional Diet Samples	October–December 1970 and Annual Summary 1970	May 1971
Strontium-90 in Tri-City Diets	January–December 1969	June 1970

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1968	August 1970
Interstate Carrier Drinking Water	1967–1969	December 1970
Kansas	January–December 1969	September 1970
Minnesota	July–December 1969	May 1971
North Carolina	January–December 1967	May 1969
New York	January–December 1969	June 1970
Radiostrontium in Tap Water, *HASL*	January–December 1969	July 1970
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	July–December 1970	May 1970
Washington	July 1968–June 1969	February 1971

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(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
Fallout in the United States and other Areas, *HASL*	July–December 1968 and January–December 1969	January 1971
Plutonium in Airborne Particulates and Precipitation	July–December 1970	June 1971
Surface Air Sampling Program, 80th Meridian Network, *HASL*	January–December 1968	April 1971

1. Radiation Alert Network February 1971

Office of Air Programs
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of the stations are operated by State Health Department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Data Acquisition and Analysis Branch, Division of Air Quality and Emission Data, EPA, Cincinnati, Ohio. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during February 1971.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, February 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Precipitation			
							Total depth (mm)	Field estimate of deposition		
			Maximum	Minimum	Average[a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	19	6	0	1	4	130	4	130	42
Alaska:	Anchorage	2	0	0	0	0				
	Attu Island	27	1	0	0	0				
	Fairbanks	0				0				
	Juneau	10	15	2	6	9	183	7	140	0
	Kodiak	15	0	0	0	0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	10	4	1	2	0				
Ark:	Little Rock	3	1	0	0	0				
Calif:	Berkeley	17	2	0	0	2	10	2	10	1
	Los Angeles	18	3	0	1	0				
C.Z:	Ancon	0				0				
Colo:	Denver	17	9	0	2	2	8	[b]		
Conn:	Hartford	18	0	0	0	9	86	9	86	2
Del:	Dover	17	0	0	0	0				
D.C:	Washington	24	1	0	0	0				
Fla:	Jacksonville	19	2	0	1	3	50	3	50	10
	Miami	14	0	0	0	3	25	2	23	0
Ga:	Atlanta	18	2	1	1	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	23	1	0	0	3	57	[b]		
Idaho:	Boise	17	3	0	1	3	18	3	18	0
Ill:	Springfield	7	1	0	1	0				
Ind:	Indianapolis	15	1	0	0	0				
Iowa:	Iowa City	17	0	0	0	5	74	5	74	0
Kans:	Topeka	19	2	0	0	4	16	4	16	1
Ky:	Frankfort	3	0	0	0	0				
La:	New Orleans	15	1	0	0	6	87	[b]		
Maine:	Augusta	2	0	0	0	1	16	1	16	0
Md:	Baltimore	17	1	0	0	8	66	8	66	0
Mass:	Lawrence	19	0	0	0	3	61	3	61	0
	Winchester	18	0	0	0	7	71	7	71	0
Mich:	Lansing	19	0	0	0	0				
Minn:	Minneapolis	19	0	0	0	3	15	3	15	2
Miss:	Jackson	13	1	0	0	3	98	3	98	0
Mo:	Jefferson City	19	3	0	1	4	50	4	50	0
Mont:	Helena	17	1	0	0	2	10	2	10	0
Nebr:	Lincoln	19	9	0	1	2	55	2	55	2
Nev:	Las Vegas	15	3	0	2	0				
N.H:	Concord	0				0				
N.J:	Trenton	18	1	0	0	7	100	7	100	4
N.Mex:	Santa Fe	18	1	0	1	0				
N.Y:	Albany	0				0				
	Buffalo	17	0	0	0	0				
	New York City	0				0				
N.C:	Gastonia	14	6	0	3	1	4	[b]		
N.Dak:	Bismarck	18	1	0	0	3	10	3	10	1
Ohio:	Cincinnati	0				0				
	Columbus	0				0				
	Painesville	20	1	0	0	11	68	11	68	30
Okla:	Oklahoma City	0				0				
	Ponca City	18	6	0	1	5	18	5	18	2
Oreg:	Portland	17	1	0	0	12	106	10	96	5
Pa:	Harrisburg	10	0	0	0	0				
P.R:	San Juan	0				0				
R.I:	Providence	17	1	0	0	0				
S.C:	Columbia	18	5	0	1	4	106	4	106	9
S.Dak:	Pierre	18	1	0	1	0				
Tenn:	Nashville	19	1	0	0	5	104	5	104	4
Tex:	Austin	5	2	1	2	0				
	El Paso	0				0				
Utah:	Salt Lake City	26	2	0	1	5	26	5	26	3
Vt:	Barre	9	0	0	0	3	62	3	62	7
Va:	Richmond	19	1	0	0	6	99	9	99	76
Wash:	Seattle	9	0	0	0	7	66	[b]		
	Spokane	13	1	0	1	0				
W.Va:	Charleston	17	1	0	0	9	79	9	79	73
Wisc:	Madison	19	1	0	0	6	84	6	84	12
Wyo:	Cheyenne	18	7	0	1	2	8	2	8	2
Network summary		898	15	0	1	172	69	5	60	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the plutonium in precipitation network. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program[1], February 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for January 1971 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, February 1971

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.2	0.1	0.1	69	0.60
Coral Harbour	4	.1	.1	.1	31	.52
Edmonton	4	.1	.1	.1	33	.47
Ft. Churchill	4	.1	.0	.1	37	.76
Fredericton	4	.1	.1	.1	26	3.58
Goose Bay	4	.1	.0	.1	22	.87
Halifax	4	.2	.1	.1	69	.60
Inuvik	4	.1	.1	.1	30	.42
Montreal	4	.1	.0	.1	24	3.06
Moosonee	4	.1	.1	.1	37	1.13
Ottawa	4	.1	.1	.1	31	5.65
Quebec	4	.1	.1	.1	15	2.08
Regina	4	.1	.1	.1	57	.28
Resolute	5	.1	.0	.1	NS	NS
St. John's, Nfld.	4	.1	.0	.1	23	1.75
Saskatoon	4	.1	.0	.1	83	.53
Sault Ste. Marie	3	.1	.0	.1	36	3.26
Thunder Bay	4	.1	.1	.1	79	5.01
Toronto	3	.1	.0	.1	89	7.27
Vancouver	4	.1	.0	.1	27	9.41
Whitehorse	4	.1	.0	.1	34	.08
Windsor	4	.1	.0	.1	44	4.06
Winnipeg	4	.1	.1	.1	161	.82
Yellowknife	3	.1	.1	.1	22	.21
Network summary	94	0.2	0.0	0.1	47	2.28

NS, no sample.

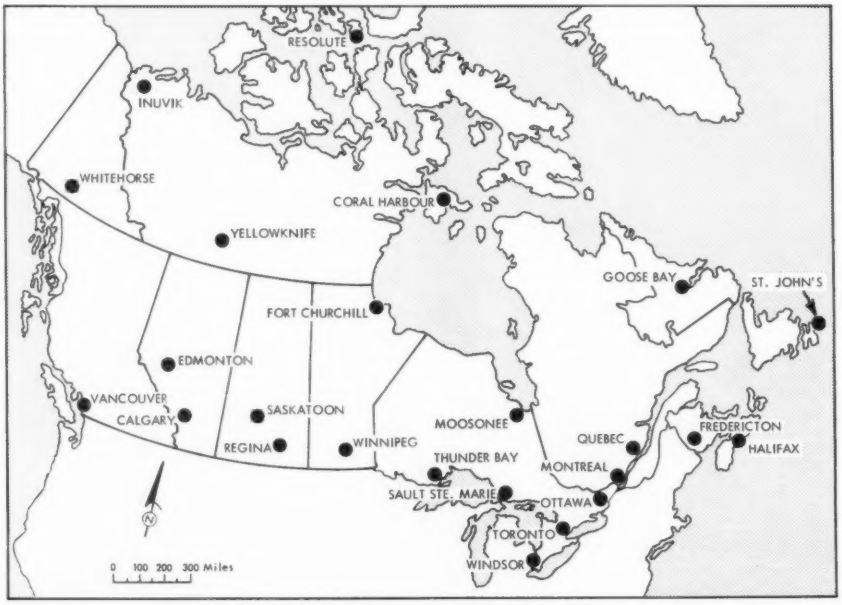

Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program February 1971

Pan American Health Organization and *Environmental Protection Agency*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The February 1971 air monitoring results from the participating countries are given in table 3.

Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, February 1971

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average[a]
Argentina: Buenos Aires	NS			
Bolivia: La Paz	17	0.04	0.00	0.02
Chile: Santiago	8	.30	.07	.18
Colombia: Bogota	18	.11	.02	.05
Ecuador: Cuenca	NS			
Guayaquil	NS			
Quito	NS			
Guyana: Georgetown	3	.29	.27	.28
Jamaica: Kingston	NS			NS
Peru: Lima	20	.19	.06	.11
Venezuela: Caracas	NS			
West Indies: Trinidad	13	.29	.04	.16
Pan American summary	79	0.30	0.00	0.10

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

4. Plutonium in Airborne Particulates July–December 1970

Office of Radiation Programs and *Office of Air Programs, Environmental Protection Agency*

The Radiation Alert Network (RAN) of the Office of Air Programs, Environmental Protection Agency, routinely collects airborne particulate samples from 11 selected RAN stations for plutonium analyses. The plutonium analyses were initiated in November 1965, and references to the previous results through December 1969 have been published (*6*).

One-half of each individual air filter from the selected stations is sent to the Northeastern Radiological Health Laboratory, Winchester, Mass. The laboratory analyzes a composite of these samples for each station on a quarterly basis. The results for July–December 1970 are presented in table 4. The minimum detectable activities are 0.020 pCi and 0.015 pCi per sample for plutonium-238 and plutonium-239, respectively. The volume of air samples varies, generally ranging from 20,000 to 30,000 cubic meters per month.

In July 1970, the Rockville, Md., RAN station was discontinued. Plutonium analyses for the Maryland area are now performed on the air filters from the Baltimore, Md., RAN station.

Table 4. Plutonium in airborne particulates, July–December 1970

Collection date (1970)	Anchorage	Phoenix	Denver	Honolulu	New Orleans	Baltimore	Buffalo	Gastonia	Pierre	Austin	Seattle
Plutonium-238: (aCi/m^3)											
July–September	[a]ND	6	6	4	5	4	6	6	4	6	4
October–December	NS	3	4	ND	2	ND	2	3	2	NS	2
Plutonium-239: (aCi/m^3)											
July–September	17	70	91	43	45	61	79	62	74	73	49
October–December	NS	40	33	15	25	22	23	30	23	NS	24
$^{239}Pu/^{238}Pu$:											
July–September	—	11.7	15.2	10.8	9.0	15.3	13.2	10.3	18.5	12.2	12.3
October–December	—	13.3	8.3	—	12.5	—	11.5	10.0	11.5	—	12.0

[a] Composite for July and August only.
ND, nondetectable.
NS, no sample.

Other coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1970	March 1971

REFERENCES

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, July-September 1970

Office of Radiation Programs
Environmental Protection Agency

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

[1] Period during which death or surgical procedure occurred.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium-90 is measured by tributyl phos-

Figure 1. Geographical regions for human bone sampling

Table 1. Strontium-90 in human bone, July–September 1970

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Northeast:						
Massachusetts	V	0	F	91.9 ± 12.5	30.6	3.00
New York	V, R	0	F	36.3 ± 5.9	19.7	1.84
	V, R	0	F	60.9 ± 5.4	30.3	2.01
	V, R, I	0	M	89.8 ± 8.2	31.3	2.87
Massachusetts	V	0	M	28.9 ± 6.9	32.8	.88
New York	V, R, I	0	M	47.2 ± 5.3	36.2	1.30
	V, R, I	0	F	37.6 ± 6.2	25.7	1.46
New Jersey	V, R	0	F	54.3 ± 7.8	40.9	1.33
New York	V	1	M	58.7 ± 9.8	25.1	2.34
	V, R, I	1	F	82.0 ± 7.6	31.5	2.60
Maine	V	2	M	82.3 ± 7.9	28.4	2.90
Massachusetts	V	2	M	82.3 ± 9.3	28.4	2.90
Connecticut	V	4	F	52.3 ± 7.0	31.0	1.69
Massachusetts	V	5	F	64.7 ± 8.7	27.2	2.38
	V	5	F	94.6 ± 9.2	26.2	3.61
New York	V	5	F	75.7 ± 11.5	33.1	2.29
	V	6	M	115.5 ± 9.2	38.9	2.97
	V	7	F	65.7 ± 10.2	31.0	2.12
New Jersey	R, S	9	M	38.5 ± 6.2	18.8	2.04
New York	V	9	M	68.7 ± 10.8	36.8	1.86
	V	10	M	38.2 ± 5.8	26.0	1.47
Massachusetts	V	11	M	62.6 ± 6.9	30.5	2.06
New York	V	14	F	63.6 ± 9.5	34.9	1.82
	V	16	M	87.6 ± 10.6	55.4	1.58
New Jersey	V, S	16	M	110.1 ± 11.3	39.7	2.78
New York	V	17	M	62.4 ± 7.6	31.4	1.98
Massachusetts	V	18	F	103.2 ± 10.3	49.1	2.10
	V	19	M	189.5 ± 18.6	51.3	3.70
Vermont	V	20	M	115.0 ± 9.7	40.1	2.87
New Jersey	S	20	M	50.1 ± 6.8	32.6	1.54
New York	V	24	M	60.4 ± 7.4	32.3	1.87
Pennsylvania	V	25	M	85.2 ± 9.2	39.0	2.18
Southeast:						
South Carolina	V	4	F	96.9 ± 10.7	27.8	3.49
	V	4	F	85.9 ± 8.7	30.3	2.84
	V	5	M	63.9 ± 7.6	30.7	2.08
North Carolina	V	5	F	113.1 ± 10.3	25.6	4.42
Maryland	V	7	F	101.6 ± 10.5	40.0	2.54
Virginia	V	9	F	74.4 ± 9.8	36.3	2.05
South Carolina	V	11	F	140.4 ± 13.7	43.7	3.21
Maryland	V	11	F	94.8 ± 12.8	48.7	1.95
North Carolina	V	14	F	165.8 ± 11.7	38.8	4.28
Tennessee	V	15	F	49.2 ± 6.7	43.9	1.12
North Carolina	V	15	F	105.3 ± 10.1	49.4	2.13
Maryland	V	15	M	89.1 ± 8.8	47.5	1.88
	V	16	M	93.2 ± 11.8	46.0	2.02
South Carolina	V	17	M	134.2 ± 11.5	47.7	2.81
	V	17	M	184.4 ± 12.1	45.8	4.02
North Carolina	V	18	M	109.2 ± 9.9	43.7	2.50
Tennessee	V	18	M	94.5 ± 10.5	51.8	1.82
North Carolina	V	21	M	114.1 ± 10.	49.9	2.29
	V	22	F	107.7 ± 13.3	44.7	2.41
Virginia	V	22	F	111.4 ± 10.3	47.2	2.36
Maryland	V	22	F	106.0 ± 11.0	59.7	1.78
South Carolina	V	22	M	64.0 ± 7.9	44.0	1.45
Maryland	V	23	M	145.6 ± 12.6	70.7	2.06
	V	23	M	111.8 ± 10.9	48.1	2.32
	V	25	F	111.2 ± 11.5	51.6	2.15
	V	25	F	79.3 ± 10.5	59.5	1.33
	V	25	F	120.6 ± 12.2	50.3	2.40
Central:						
Ohio	V	0	M	72.0 ± 11.5	34.2	2.10
	V	0	F	68.2 ± 5.8	23.3	2.93
Wisconsin	V	2	M	71.3 ± 9.0	28.7	2.49
	V	3	F	5.3 ± 6.3	28.3	.19
	V	4	F	52.5 ± 10.0	63.4	.83
Ohio	V	6	F	62.9 ± 9.9	29.0	2.17
	V	6	M	101.5 ± 12.2	34.9	2.91
Michigan	V	6	F	57.9 ± 8.2	29.7	1.95
Wisconsin	V	7	M	54.6 ± 6.5	32.8	1.67
Michigan	V, R	7	F	225.3 ± 19.1	61.6	3.66
Ohio	V	9	M	41.9 ± 6.9	24.9	1.68
Wisconsin	V	10	F	75.7 ± 8.2	31.9	2.37
Minnesota	V	11	M	58.3 ± 6.7	38.0	1.54
Wisconsin	V	11	F	92.4 ± 8.8	51.7	1.79
Ohio	V	13	M	109.5 ± 9.8	54.5	2.01
	V	13	M	143.3 ± 12.1	51.3	2.80
	V	13	M	94.5 ± 13.4	50.9	1.86
Minnesota	V	14	M	54.8 ± 7.1	37.7	1.45
Ohio	V	14	M	320.9 ± 19.5	52.2	6.15
	V	15	F	88.2 ± 11.6	45.8	1.93
Minnesota	V	16	F	69.6 ± 6.8	42.9	1.62

See footnotes at end of table.

Table 1. Strontium-90 in human bone, July–September 1970

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Central (Continued)						
Ohio	V	16	F	182.6 ± 16.4	50.9	3.58
	V	18	M	95.4 ± 11.0	56.5	1.69
	V	19	M	147.0 ± 12.8	71.8	2.05
	V	19	M	103.1 ± 12.6	57.6	1.79
	V	19	M	106.0 ± 9.5	58.7	1.81
	V	19	F	136.2 ± 13.0	47.9	2.84
South Dakota	V	19	M	67.7 ± 7.5	40.7	1.66
Michigan	V	19	M	107.7 ± 12.9	64.5	1.67
Ohio	V	20	F	86.2 ± 12.2	59.1	1.46
	V	20	M	86.6 ± 7.6	46.0	1.88
	V	22	M	68.6 ± 7.1	46.0	1.49
	V	22	M	83.6 ± 10.1	52.4	1.60
Michigan	V	22	F	39.5 ± 6.9	45.1	.88
Ohio	V	22	M	80.2 ± 9.1	66.9	1.20
	V	23	M	99.9 ± 12.5	50.5	1.98
	V	23	F	84.0 ± 9.3	49.1	1.71
	V	23	F	58.4 ± 8.0	50.6	1.15
Kansas	V	24	M	79.6 ± 10.4	54.6	1.46
Ohio	V	24	F	69.9 ± 7.3	46.7	1.50
	V	25	M	120.2 ± 11.3	62.6	1.92
	V	25	M	86.5 ± 8.8	47.9	1.81
Delta:						
Louisiana	V	2	F	62.7 ± 10.1	27.7	2.26
	V	6	F	132.1 ± 12.0	35.7	3.70
	V	9	M	41.3 ± 8.1	27.1	1.52
	V	18	M	160.6 ± 17.6	57.7	2.78
Northwest:						
Oregon	V	4	M	82.5 ± 10.0	34.9	2.36
Southwest:						
Texas	V	10	M	37.3 ± 7.3	29.1	1.28
	V	16	M	59.9 ± 7.4	29.0	2.07
	V	20	F	60.2 ± 11.1	54.5	1.10

[a] Type of bone, V, vertebrae; R, rib; S, sternum; I, Ilium.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

phate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples.

The analytical results for strontium-90 in individual bones from persons dying during the third quarter (July–September) of 1970 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–6*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1970	January 1971
April–June 1970	April 1971

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Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Atomics International and Hanford Atomic Products Operation.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International[2] July–December 1970

North American Rockwell Corporation
Canoga Park, Calif.

Atomics International, a division of North American Rockwell Corporation, has engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants, and for medical, industrial, and scientific applications.

[2] Summarized from "Environmental Monitoring, Semiannual Report, July 1 to December 31, 1970," Atomics International, Division of North American Rockwell Corporation.

The company headquarters is located in Canoga Park, Calif., approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is located in the Simi Hills of Ventura County, approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International requires adequate containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a measure of the effectiveness of the company's radiological

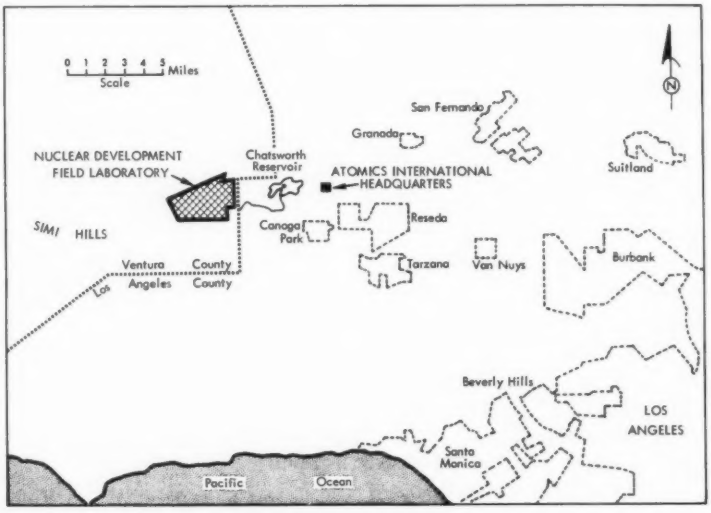

Figure 1. Atomics International facilities and vicinity

safety procedures and of engineering safeguards incorporated into facility designs.

The onsite environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. The offsite environs are sampled monthly, except for soil and vegetation which are sampled quarterly. In addition, continuous environmental air monitoring at the sites provides information concerning long-lived airborne particulate radioactivity.

Counting and calibration procedures

Beginning in July 1970, radioactivity determinations for all environmental soil, vegetation, water, and air samples are performed with a low-background proportional counting system capable of simultaneous counting of both alpha and net beta radioactivity. The system permits the use of larger samples, thereby increasing the overall sensitivity to low radioactivity concentrations. The sample-detector configuration provides a nearly 2π geometry. The thin-window detector is continually purged with methane counting gas. A preset time mode of operation is used for all samples; however, an overriding preset count mode is available to limit the counting time for high activity samples.

The minimum detection limits shown in table 1 pertain only to the low-background counting system used during the last half of 1970. They were determined by using typical values for counting time, system efficiency, background count rates (approximately 0.05 cpm alpha and 1.0 cpm beta-gamma), and sample size. In addition, the minimum statistically significant amount of radioactivity, irrespective of sample configuration, is established as that amount equal in count rate to three times the standard deviation of the system background count rate.

Counting system efficiencies are determined routinely with RaD + E + F (with alpha absorber), thorium-230, and uranium-235 standard sources, and with potassium-40 in the form of standard reagent grade KCl, which is used to simulate soil and vegetation samples. Self-absorption standards are made by dividing sieved KCl into samples increasing in mass by 200-milligram increments from 100 to 3,000 milligrams. The samples are placed in copper planchets of the type used for environmental samples and counted. The ratio of disintegration rate to the observed net count rate for each sample is plotted as a function of sample weight (figure 2). The correction factor (ratio) corresponding to the environmental sample weight is obtained from the graph. The product of the correction factor and the net environmental sample count rate yields the sample activity (dpm). This method has been checked successfully by applying it to aliquots of uniformly mixed environmental samples of various weights and observing that the resultant specific activities fall within the expected statistical counting error.

Table 1. Minimum radioactivity detection limits

Sample	Radioactivity	Minimum detection limits (standard error)
Soil	Alpha	0.05 ± 0.03 (pCi/g)
	Beta-gamma	.22 ± .11 (pCi/g)
Vegetation	Alpha	.10 ± .06 (pCi/g-ash)
	Beta-gamma	.35 ± .18 (pCi/g-ash)
Water	Alpha	.20 ± .12 (pCi/liter)
	Beta-gamma	.63 ± .32 (pCi/liter)

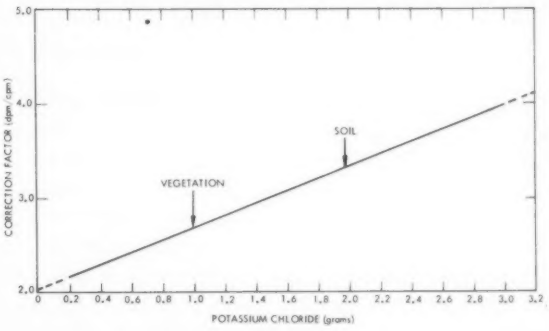

Figure 2. Sample self-absorption correction graph

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV-70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity has been allowed to decay for at least 72 hours. The volume

of a typical daily environmental air sample is approximately 20 cubic meters. The average concentration of long-lived beta-gamma radioactivity of airborne particulates is presented in table 2 for July–December 1970.

Table 2. Beta-gamma radioactivity of airborne particulates, Atomics International, July–December 1970

Location	Number of samples	Average concentration[a] (pCi/m³)
Headquarters	344	0.22
NDFL	1,222	.25

[a] Minimum detectable level—0.04 pCi/m³.

When abnormally high airborne radioactivities are observed, the radioactivity decay data are plotted to determine the presence of short-lived isotopes other than naturally occurring radon, thoron, and daughters. If fallout is suspected, the decay characteristics are observed. If the radioactivity decays as a function of $t^{-1.2}$, the data are extrapolated to determine the date of origin. This date is compared with the dates of publicized nuclear detonations to determine if the abnormal airborne radioactivity could have been caused by such detonations.

A graph of averaged long-lived airborne radioactivity concentrations detected at the Headquarters and NDFL facilities during the second half of 1970 is presented in figure 3. The graph shows a generally decreasing concentration trend through the fall months with a prominent peak noted in November.

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 3.

Soil, vegetation, and water are sampled monthly at Chatsworth Reservoir which is operated by the

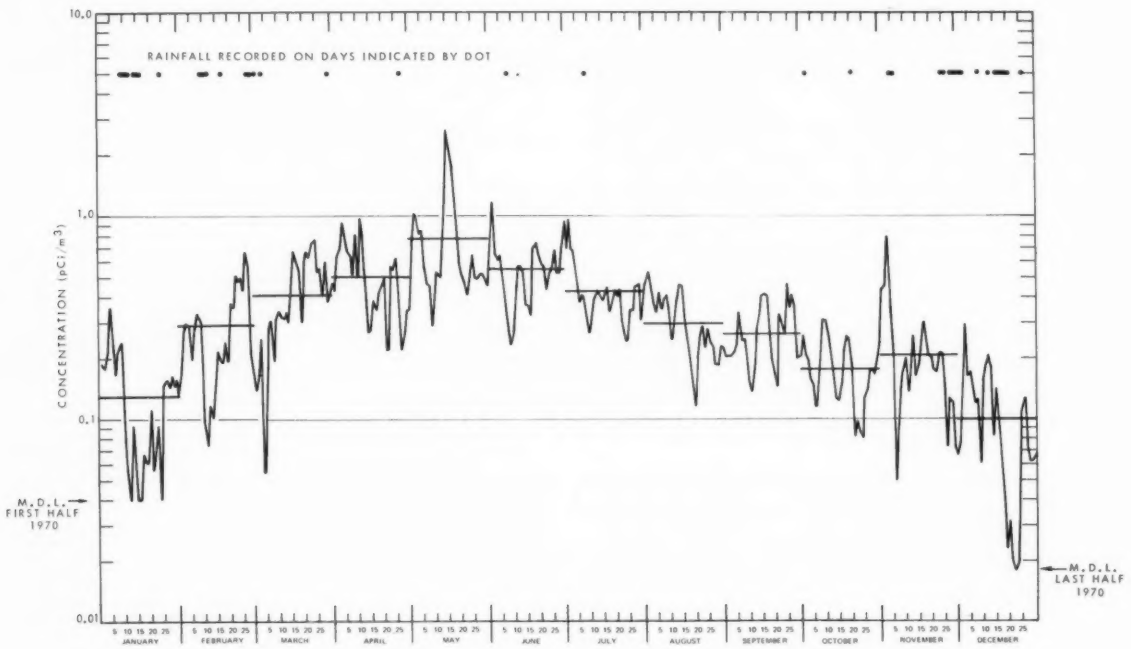

Figure 3. Long-lived radioactivity at Headquarters and NDFL, January–December 1970

Table 3. Process water radioactivity, NDFL site July–December 1970

Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Alpha	12	0.30
Beta-gamma	12	4.9

Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface, and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The lake was drained in July 1969 for construction, thereby precluding surface sampling for all of 1970. The average radioactivity concentration in reservoir supply water samples is presented in table 4.

Table 4. Chatsworth Reservoir water radioactivity Atomics International, July–December 1970

Sample	Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	0	–
	Beta-gamma	0	–
Supply inlet	Alpha	6	0.54
	Beta-gamma	6	4.9

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66-49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 2.5 miles downstream from the south NDFL boundary. Samples, obtained and analyzed monthly, include stream-bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 5.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 25 locations. Eleven sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 14 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Table 5. Radioactivity in the Rocketdyne reservoir and Bell Creek,[a] July–December 1970

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir station 6, water[a] (pCi/liter)	6	0.24	7.1
Reservoir station 12, water[a] (pCi/liter)	6	.16	7.2
Bell Creek, mud (pCi/g)	6	.54	24
Bell Creek, vegetation (pCi/g ash)	6	.18	160
Bell Creek, water (pCi/liter)	6	.28	3.4

[a] Location not shown on figure 1.

Surface soil types that are available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 6.

Table 6. Radioactivity in the soil, Atomics International, July–December 1970

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.54
	Beta-gamma	72	25
Offsite	Alpha	24	.55
	Beta-gamma	24	24

Vegetation samples obtained in the field are of the same plant type wherever possible, generally sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 7.

Table 7. Radioactivity in vegetation, Atomics International, July–December 1970

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.26
	Beta-gamma	72	150
Offsite	Alpha	24	.30
	Beta-gamma	23	129

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1969	August 1970
January–June 1970	February 1971

2. Hanford Atomic Products Operation[3] January–December 1968

Battelle Memorial Institute
Richland, Wash.

A variety of radioactive wastes are generated by the Hanford production reactors, chemical separations plants, and laboratories. High-level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage are not feasible, are made to the ground, to the atmosphere, and to the Columbia River. The Atomic Energy Commission (AEC) regulations governing radioactive waste disposal at Hanford are described in the AEC Manual Chapter RL 0510 (*1*). During 1968, the plant facilities were operated for the Atomic Energy Commission by: Atlantic Richfield Hanford Company; Pacific Northwest Laboratories of Battelle Memorial Institute; Douglas-United Nuclear, Incorporated; and ITT Federal Support Services, Incorporated.

The Hanford site is in a semiarid region of southeastern Washington State (figure 4) where the average rainfall is about 16 cm (6 inches). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the site have gradually been put under irrigation during the past few years. The plant site covers an area of about 1,300 km² (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Prevailing winds near the plant production sites are from the northwest, with strong drainage and cross winds

[3] Summarized from Pacific Northwest Laboratory, "Evaluation of Radiological Conditions in the Vicinity of Hanford for 1968," BNWL–1341 (May 1970).

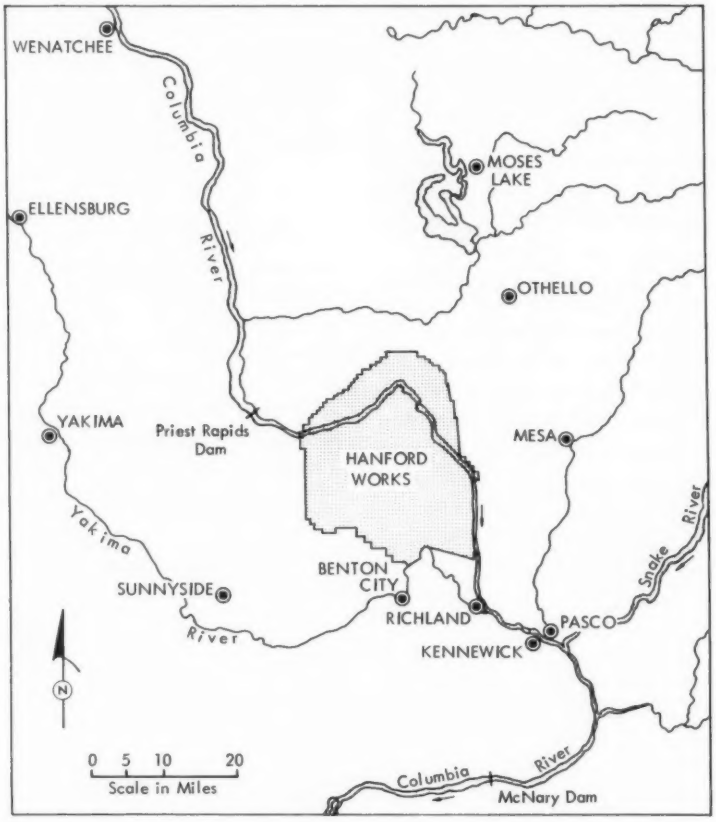

Figure 4. Hanford project environs

causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated area of primary interest is the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant, together with the surrounding agricultural area, is about 95,000.

Sources and levels of environmental radioactivity

Low-level wastes from plant operations, fallout from nuclear weapons testing, naturally occurring radioelements, and cosmic rays contribute to radioactivity in the Hanford environs. Hanford operations that could contribute to radioactivity outside the plant boundary are: (1) the disposal of reactor cooling water to the Columbia River, (2) stack releases at the chemical separations areas and laboratory areas, and (3) disposal of radioactive wastes to ground.

The most significant Hanford contributions to off-plant radioactivity and population doses usually originate with reactor cooling water released to the Columbia River. Although airborne releases of iodine-131 have contributed in past years to the thyroid doses of the local population, the major portion of the thyroid doses in 1968 resulted from radioiodines in drinking water.

Noteworthy events during 1968 included the retirement in mid-February of B reactor, the fifth Hanford production reactor to be retired since 1964. Four plutonium production reactors (including the dual-purpose N reactor) remained in operation. Increases in atmospheric total beta concentrations in January with sustained high concentrations throughout the first part of the year were attributed primarily to an announced foreign weapons test in December 1967 (*2*).

Radioactivity in the Columbia River

Nuclides present in reactor effluent

Cooling of the Hanford production reactors (with the exception of N reactor) is accomplished by a single pass of treated Columbia River water. The N reactor uses recirculating demineralized water as a primary coolant, and all wastewater containing significant amounts of radioactive material is discharged to a ground disposal site near the river. Although some of these radionuclides eventually enter the river, the total quantity of radioactivity entering the Columbia River from N reactor is a negligibly small fraction of that released from the older reactors.

At the older reactors, some elements present in the cooling water are activated during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river. Table 8 shows the relative abundance of the radionuclides found in the cooling water of the older production reactors, adjusted to 4 hours after leaving the reactor.

Table 8. Relative abundance of reactor effluent radionuclides[a]

Percent of abundance				
Major (90 percent)	Minor (9 percent)	Trace (1 percent)		
^{24}Na	^{32}P	^{3}H	^{91}Y[b]	^{143}Ce[b]
^{31}Si	^{46}Sc	^{14}C	^{93}Y[b]	^{144}Ce[b]
^{51}Cr	^{69m}Zn	^{35}S	^{95}Nb	^{142}Pr[b]
^{56}Mn	^{72}Ga	^{45}Ca	^{99}Mo	^{143}Pr[b]
^{64}Cu	^{76}As	^{54}Mn	^{103}Ru	^{147}Nd[b]
	^{92}Sr	^{59}Fe	^{106}Ru	^{147}Pm[b]
	^{122}Sb	^{60}Co	^{124}Sb	^{149}Pm[b]
	^{132}I	^{63}Ni	^{131}I	^{151}Pm[b]
	^{140}La[b]	^{65}Zn	^{133}I	^{152}Eu[b]
	^{152m}Eu[b]	$^{87.0}$Sr	^{135}I	^{156}Eu[b]
	^{153}Sm[b]	^{89}Sr	^{136}Cs	^{153}Gd[b]
	^{165}Dy[b]	^{90}Sr	^{137}Cs	^{159}Gd[b]
	^{239}Np	^{91}Sr	^{140}Ba	^{160}Tb[b]
		^{90}Y[b]	^{141}Ce[b]	^{161}Tb[b]
				^{166}Ho[b]
				^{169}Er[b]
				^{171}Er[b]

[a] Trace nuclide composition based on analyses, 1964 and 1968.
[b] These radionuclides as a group are denoted hereafter as RE+Y (rare earths+yttrium).

Many of the radionuclides formed in reactor cooling water are short-lived and disappear quickly due to radioactive decay. In addition, sedimentation and uptake by aquatic organisms remove some fraction of most radionuclides from the river water. The relatively small amounts of fission products present in the river can be attributed to the fissioning of natural uranium present in the river water, occasional ruptures of the fuel element jackets, and fallout from nuclear weapons testing.

Some radionuclides also enter the river from

wastes disposed to ground, but their contribution to the total radioactivity is extremely small.

River flow rates

The seasonal fluctuations in flow rate of the Columbia River affect radionuclide concentrations by varying the quantity of water available for dilution of reactor effluent released to the river. In addition, the seasonal scouring of sediments deposited in reservoirs behind each dam causes seasonal fluctuations in transport rates of those longer-lived nuclides associated with the sediments. This is notably true for scandium-46 and zinc-65. Also affected by the flow rate is the time required for a specific volume of water to move from one location to another which in turn affects the amount of decay of the shorter-lived nuclides that will occur before these nuclides reach a particular location on the river.

The weekly average flow rates of the Columbia River at Priest Rapids and Bonneville Dams are determined from daily average flow rates published by the U.S. Geological Survey (*3*). For 1968, the average river flow rate at Priest Rapids was 3,380 m^3/s (120,000 ft^3/s), which was below the 1948–1962 annual average of 3,770 m^3/s (133,000 ft^3/s).

River concentrations

During 1968, samples of river water were collected above the production reactor areas at Priest Rapids Dam and below the areas at the Richland water plant intake, McNary Dam and Bonneville Dam. Where possible, cumulative sampling equipment was used to provide a more representative sample than periodic "grab" samples. This cumulative sampling technique, however, prevents calculation of the concentrations of radionuclides with very short half-lives; these were measured in monthly "grab" samples (*4*).

Table 9 shows the annual average radionuclide concentrations in river water at Richland and at Bonneville Dam for 1965–1968. The data for 1966 include the effects of reactor outages during the July–August strike. Comparison of 1968 with 1967 concentrations indicates a general reduction for most radionuclides. Part of the apparent reduction in phosphorus-32 at Richland is attributed to a change from "grab" to cumulative sampling. For example, the average of the cumulative samples during 1967 was 130 pCi/liter compared to 190 pCi/liter for "grab" samples of phosphorus-32. In 1968, concentrations of the short-lived radionuclides were expected to be lower than in previous years because fewer production reactors remained

Table 9. Annual average concentrations of several radionuclides in Columbia River water, 1965–1968

Radionuclide	Concentration (pCi/liter)							
	1965		1966		1967		1968[a]	
	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam	Richland	Bonneville Dam
Rare earths + yttrium	730	(b)	270	(b)	390	(b)	280	(b)
Hydrogen-3	(b)	(b)	(b)	(b)	1,500	(b)	1,700	(b)
Sodium-24	3,100	(b)	2,600	(b)	2,600	(b)	2,200	(b)
Phosphorus-32	140	23	140	23	190	25	92	15
Scandium-46	(b)	(b)	30	(b)	60	18	100	20
Chromium-51	7,000	1,700	3,600	1,300	3,200	1,400	1,500	530
Manganese-56	390	(b)	290	(b)	520	(b)	250	(b)
Copper-64	2,500	(b)	1,400	(b)	2,000	(b)	1,200	(b)
Zinc-65	180	70	200	43	220	62	86	<30
Arsenic-76	1,000	(b)	420	(b)	400	(b)	320	(b)
Strontium-90	1	(b)	1	(b)	1	(b)	< .6	(b)
Zirconium-niobium-95	(b)	(b)	(b)	(b)	(b)	<5	<6.3	(b)
Technetium-99	(b)	(b)	(b)	(b)	<5	(b)	<11	(b)
Ruthenium-106	(b)	(b)	(b)	(b)	(b)	<5	<5	(b)
Antimony-122	(b)	(b)	(b)	(b)	150	(b)	150	(b)
Iodine-131	10	3	18	3	8	3	7.4	<3.2
Neptunium-239	1,600	(b)	770	(b)	1,100	(b)	1,000	(b)
Total alpha	<1.1	(b)	<1.3	(b)	<1.2	(b)	[c]1.3	(b)

[a] During 1968, results for ^3H, ^{32}P, ^{46}Sc, ^{51}Cr, ^{65}Zn, ^{95}Zr-Nb, ^{90}Sr, and ^{131}I were based on cumulative samples.
[b] Indicates insufficient data to provide a meaningful annual average.
[c] Based on grab samples (January–June) and on cumulative samples (July–December).

in operation. Moreover, the operating reactors are farther upstream than the retired reactors (except "B" reactors). As in past years, total alpha concentrations measured in river water at Richland were near the analytical limit (1 pCi/liter) and were not significantly different from those measured in samples collected upstream from the Hanford project.

Concentrations of tritium in river water are measured upstream from Hanford at Priest Rapids Dam and downstream from Hanford at Richland. The average concentrations of tritium at Priest Rapids Dam and Richland were not significantly different at 1.6 and 1.7 nCi/liter, respectively, compared to 1.4 and 1.5 nCi/liter at these locations during 1967.

Sampling traverses across the Columbia River at Richland have indicated a slightly nonuniform distribution of the longer-lived radionuclides at this cross section. Entries of the Yakima River just below Richland and of the Snake River just below Pasco influence the distribution of radionuclides in the Columbia below these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries.

Bonneville Dam, approximately 490 km (240 miles) below the Hanford reactors, is the farthest downstream location where river water is routinely sampled as part of the Hanford environmental surveillance program. Measurements at this location provide an upper limit to the annual transport of specific nuclides into the Pacific Ocean (table 10).

Table 10. Annual average transport rates of selected radionuclides past Bonneville Dam, 1964–1968

Radionuclides	Transport rate (Ci/day)				
	1964	1965	1966	1967	1968
Phosphorus-32	12	11	9	12	6.2
Scandium-46	NA	NA	NA	10	7.5
Chromium-51	860	800	430	610	200
Zinc-65	44	49	21	40	<13

NA, indicates no routine analysis was made.

Transport rates

Table 10 shows the annual average transport rates of selected radionuclides past Bonneville Dam. Transport rates of 84-day scandium-46 increased to detectable values in 1967. The transport rates at Richland in 1968 for the radionuclides shown were all lower than the 1967 values, primarily due to changes in reactor operation and the retirement of the "B" reactor.

Trend indicator—whitefish

The Columbia River is popular for sports fishing both above and below the Hanford reservation. Fish that feed downstream from the reactors acquire some reactor-effluent radionuclides through food chains with phosphorus-32 being the most significant in regard to population doses. Changes in river concentrations and temperatures may induce changes in concentrations in biological media. However, the ultimate uptake of radionuclides depends on complex environmental interrelationships. Whitefish is the sports fish that usually contains the greatest concentration of radioactive materials. Furthermore, it can be caught during winter months when other sports fish are difficult to sample. Therefore, phosphorus-32 data accumulated from whitefish sampling near the plant boundary are useful as a trend indicator of concentrations in biological media even though whitefish is not the most significant source of radionuclides for the local population.

Concentrations of phosphorus-32 in whitefish during 1968 tended to follow the same seasonal trends observed in past years. The average concentrations of phosphorus-32 in whitefish sampled downstream from the reactors during 1968 was 140 pCi/g, as compared with 260 pCi phosphorus-32/g during 1967 (*5*). The lower average phosphorus-32 concentration in 1968 was attributed to decreased concentrations of phosphorus-32 in the river and decreased river temperatures.

Radioactivity in groundwater

Radioactivity in the groundwater beneath the Hanford project results primarily from ground disposal of wastes in the chemical separations areas. These wastes are routed to various facilities dependent upon their radionuclide burden and chemical content. High-level wastes[4] are stored in

[4] High-level: >100 μCi/ml.

underground concrete tanks lined with steel. Intermediate-level wastes[5] are sent to underground "cribs" (covered liquid waste disposal sites) from which they percolate into the soil. The areas selected for intermediate-level waste disposal and high-level waste storage have soil with good ion exchange capacity and groundwater depths of 50 to 100 m. Low-level wastes[6] are usually sent to depressions in the ground where surface ponds or "swamps" have been formed as the result of the continuous addition of relatively large volumes of water.

One important objective in the management of wastes placed in the ground is the prevention of radiologically important radionuclides from reaching the groundwater in quantities that could ultimately cause significant human radiation exposure should they migrate to the Columbia River. An extensive groundwater surveillance program is maintained at Hanford to aid in achieving this objective. Hundreds of wells have been drilled at various locations around the Hanford project, including sites within and near crib and tank storage areas, to monitor the movement of radionuclides in the groundwater.

The radioactivity in groundwater from the chemical separations areas outside the immediate vicinity of the disposal sites is primarily tritium and ruthenium-rhodium-106, although cobalt-60 and technetium-99 have also been found but at much lower concentrations. The more radiotoxic nuclides, such as strontium-90, have not been detected in groundwater except in the immediate vicinity of a few specific disposal sites.

Figures 5 and 6 show the probable extent of detectable tritium and ruthenium-rhodium-106 in groundwater beneath the Hanford project as of December 31, 1968 (*6*). The outer boundaries of the contamination contours, e.g., 0.1 percent for tritium and 2 percent for ruthenium-rhodium-106, represent the detection levels routinely achievable for these radionuclides (*1*).

In all probability, some radionuclides from the chemical processing areas are presently entering the Columbia River. However, the concentrations of these nuclides are too small to be routinely measurable in the groundwater near the river or in the river itself, and any radiation dose from them is negligible.

Radioactivity in the atmosphere

At Hanford, gaseous wastes from the chemical separations facilities are released to the atmosphere through elevated stacks after most of the radioactive materials have been removed. Laboratory stacks, reactor-building stacks, and stacks from waste-storage facilities release relatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne iodine-131, the radionuclide of primary interest, were made routinely during 1968 at about 30 locations within and near the Hanford reservation. The results of iodine-131 measurements for four selected locations for the past few years, which include contributions from offsite weapons tests, are summarized in table 11. The locations listed in table 11 lie within a 45° sector southeast to south of the separations areas. The environmental iodine-131 concentrations for 1968 averaged less than the analytical limit of 0.02 pCi/m³ at Richland, Pasco, and Kennewick. A sustained concentration of iodine-131 at this level in breathing air would imply an annual radiation dose to the thyroid of the standard man of less than 1 mrem from inspired air[7] (*7*).

Continuous sampling for radioactivity associated with airborne particulates was maintained as of the end of 1968 at 35 locations, including those within the Hanford reservation and around the plant perimeter at distances up to 75 miles.

Table 11. Annual average iodine-131 concentrations in the atmosphere, 1964–1968

Location	Distance from separation stacks (miles)	Iodine-131 (pCi/m³)				
		1964	1965	1966	1967	1968
Prosser barricade[a]	14	0.02	0.03	0.02	0.02	0.01
Benton City	20	.06	.03	.01	.02	.01
Richland	20	.02	.02	.01	.02	.02
Pasco	32	.01	.03	.01	.02	.02

[a] Sampling was discontinued in April 1968.

[5] Intermediate-level: 50 pCi/ml to 100 μCi/ml.
[6] Low-level: <50 pCi/ml.

[7] Assuming that volume breathing rate is proportional to thyroid size, the thyroid dose from inhalation of iodine-131 is independent of age and thyroid size (*8*).

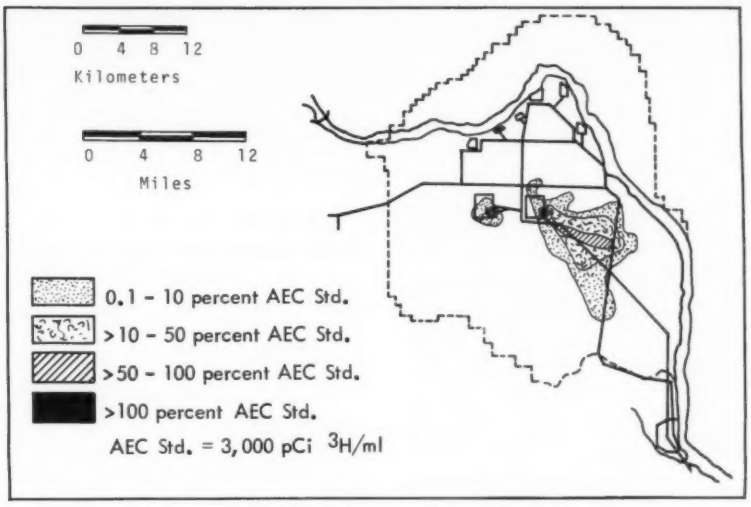

Figure 5. Tritium concentrations in ground water, Hanford July–December 1968

The gross beta activity of each sample filter was routinely measured (based on strontium-yttrium-90 standard) with detailed radioanalyses performed on filters showing unusual beta radioactivity.

The higher atmospheric concentrations of radioactive particulate material during the first half of 1968 compared to fall 1967 were attributed primarily to fallout following a foreign nuclear weapons test in late December 1967. The observed concentrations were comparable to those observed during similar events of recent years. A similar increase in total beta concentrations was noted in December 1968; however, no significant increase was noted in the Southeast quadrant locations because of the nonuniform geographical distribution of increased concentrations. The increase was attributed to fallout from an offsite source and the contaminant was identified as radiotungsten.

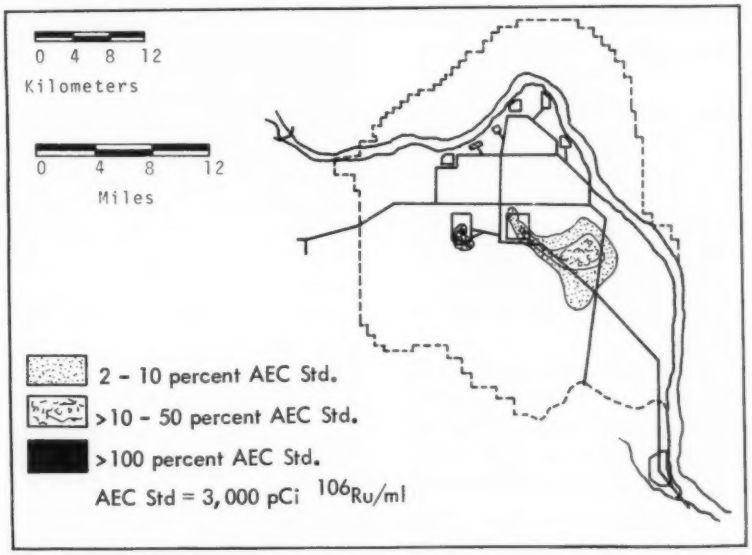

Figure 6. Ruthenium-106 concentrations in ground water, Hanford July–December 1968

Fallout from nuclear weapons tests

Fresh fallout in early 1968, resulted from an announced foreign nuclear weapons test in December 1967 (*2*). Airborne particulate radioactivity concentrations were higher during the first half of 1968 as a result of the December 1967 event. Atmospheric concentrations of iodine-131 were within the normal range of fluctuation from plant sources, but iodine-131 concentrations in milk samples reached a peak of 25 pCi/liter in January. For comparison, in January 1967, the peak iodine-131 concentration in milk was 83 pCi/liter as a result of fallout from a foreign weapons test in December 1966.

In December 1968, a general increase in beta radioactivity in the atmosphere was attributed to regional fallout from an event at the Nevada Test Site with the highest concentration of particulate radioactivity (3.9 pCi/m^3) at Walla Walla during the period, December 6 through December 20, 1968 (*2*). The principal gamma-emitter was identified as radiotungsten.

No significant contribution to atmospheric radiation levels was detected in December samples following the announced foreign nuclear weapons test of December 27, 1968 (*9*).

Exposure pathways

Radionuclides in drinking water

The city of Richland is the first community downstream from the Hanford reactors that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few kilometers farther downstream, also use the Columbia River as a source of drinking water. The Richland and Pasco water plants use a modern flocculation-filtration method; Kennewick water is pumped from Rainey well collectors (infiltration pipes) laid in the riverbank. During 1968, cumulative drinking water samples were collected at the Richland and Pasco water plants and periodic samples at all three communities. All of these samples were analyzed for important individual radionuclides. Detailed analyses of drinking water from these three cities are summarized in table 12. In June, analyses of individual radionuclides in samples from Kennewick were discontinued because previous experience had shown that concentrations of radionuclides in Kennewick water were significantly lower than those at Pasco or Richland. Kennewick samples continued to be analyzed for gross beta radioactivity.

Table 12. Average concentrations[a] of several radionuclides in drinking water, 1968

Radionuclide	Radioactivity concentration (pCi/liter)		
	Richland	Pasco	Kennewick[b]
Rare earths+yttrium	46	20	9
Sodium-24	1,600	350	140
Phosphorus-32	48	30	13
Chromium-51[c]	1,400	1,400	480
Copper-64	350	<51	38
Zinc-65[c]	38	35	<24
Arsenic-76	140	33	15
Strontium-90[c]	<0.6	<0.5	NA
Antimony-122	120	100	22
Iodine-131[c]	6.9	5.9	<2
Iodine-133	[d]41	[e]24	NA
Neptunium-239	670	340	57
Total beta, counts/min-ml	2.9	1.2	.3

[a] Measured at the water plants.
[b] Kennewick concentrations were based on monthly grab samples collected January through June except for total beta which was based on weekly grab samples throughout the year.
[c] Results based on cumulative samples at Richland and Pasco.
[d] Estimate based on an average ratio of $^{133}I/^{131}I$ of 6:1 measured in grab samples.
[e] Estimate based on an average ratio of $^{133}I/^{131}I$ of 4:1 measured in grab samples.
NA, no analysis.

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 12 because there can be a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand. In Richland, many residents receive no radioactivity of Hanford origin in drinking water during the times of the year when well water is used to supplement the system supply.

Table 13 presents calculated doses to the adult whole body, GI tract, and bone from sustained consumption at a standard intake of 1.2 liters per day, and to the infant-2 gram thyroid from consumption of 0.4 liters per day of drinking water in Richland and Pasco. Average concentrations of radionuclides measured at the water plants were used to calculate these doses. However, thrice-weekly measurements of gross beta radioactivity were also used in establishing the GI-tract dose.

The dose estimates for Pasco residents reflect a downward trend from 1967. The thyroid dose for 1968 from Pasco drinking water (32 mrem) was slightly less than that for 1967 (35 mrem) because of the decreased concentration of iodine-131. The average ratio of iodine-133 to iodine-131 of 4:1 for Pasco in 1968, which was based on 1968 measurements on grab samples, was the same as the assumed ratio in 1967.

Table 13. Calculated annual doses to selected organs from routine ingestion of drinking water, 1968[a]

Location	Whole body (mrem)	GI tract (mrem)	Bone (percent of MPRI)	Thyroid (infant) (0.4 liters/day) (mrem)
Richland	1.5	18	4.0 (0.1)	48
Pasco	0.5	12	2.5 (<0.1)	32

[a] The "standard man" (*20*) average intake rate of 1.2 liters/day was used in this calculation with the exception of the thyroid.

The estimated GI tract dose to Richland residents from the measured radionuclides in drinking water was somewhat lower in 1968 (18 mrem) than in 1967 (28 mrem) as a result of the decreased concentrations of most measured radionuclides and a decrease in the average gross beta radioactivity from 4.7 in 1967 to 2.9 counts/min-ml in 1968. The infant thyroid dose appears somewhat higher during 1968 than during 1967 because the estimated contribution of iodine-133 was based on an assumed ratio of iodine-133 to iodine-131 of 4:1 in 1967 (*5*). Measurements during 1968, however, indicated a slightly higher ratio (6:1). Without the increment from iodine-133, the estimated thyroid dose for 1968 would have been lower than for 1967.

Radionuclides in Columbia River fish

The quantities and kinds of fish caught by local fishermen have been previously estimated from surveys carried out from 1963 to 1965 in cooperation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals per year of panfish species (crappie, perch, and bass) taken from the Columbia River. Additional dietary data collected during 1966 and 1967 from household questionnaires and interview surveys also showed individual consumption estimates as high as 200 meals of fish per year.[8] The primary fishing locations for the catch of these fish were Burbank, Hover-Finley, and Island View. The average percentage of the maximum catch by species was 73 percent crappie, 16 percent bass, and 11 percent perch.

From this species distribution and radiochemical analyses of the specimens collected, the "maximum individual's"[9] estimated intakes during 1968 were 1.0 μCi phosphorus-32 and 0.4 μCi zinc-65 (*4*).

The average consumption of Columbia River fish by Richland residents was estimated from plant employee diet questionnaires (*5*). With the use of the same mixture of species as for the "maximum individual," the "average Richland resident's"[10] intake during 1968 was 0.012 μCi phosphorus-32 and 0.004 μCi zinc-65. Such an intake corresponds to a bone dose of slightly more than 2 mrem or about 0.5 percent of the standard of 500 mrem per year for the population average. For comparison, intakes during 1967 were 0.019 μCi phosphorus-32 and 0.004 μCi zinc-65.

Radionuclides in game birds

Migratory waterfowl utilizing the river downstream from the reactors and upland game birds living near the river may be a significant source of the bone-seeking radionuclides (phosphorus-32 and zinc-65) for persons who consume such birds. The concentrations of radionuclides in game birds at the time of consumption are dependent upon the bird species, the geographical locations of the birds, and the elapsed time between killing and consumption of the birds.

For the past 2 years, about 16 km² (4,000 acres) of the Hanford site situated north of Ringold on the eastern side of the Columbia River has been opened to hunters during hunting seasons. This area which is adjacent to the river was visited in 1968 by 1,537 hunters for an average of about 33 hunters on each of the 46 open days (*10*). For

[8] Fisherman survey by J. K. Soldat, Battelle-Northwest, Richland, Wash. (report in preparation).
[9] See page 356 for definition of term.
[10] See page 359 for definition of term.

comparison, the average for 1967 was about 50 hunters on each of the 48 open days (*10*).

The average concentration of phosphorus-32 in the muscle (the edible portion) of waterfowl collected at the Hanford site for the environmental monitoring program during 1968 was about 53 pCi/g for ducks and 1.4 pCi/g for geese. The maximum concentration in waterfowl during 1968 was 450 pCi phosphorus-32/g, which is significantly lower than the maxima observed in the past few years. Average concentrations in muscle for upland game birds collected at the Hanford site appear in table 14. The maximum phosphorus-32 concentration in upland game bird muscle was 490 pCi phosphorus-32/g in a quail sample. If a small child (2 kg skeleton) had immediately consumed 100 grams of this quail, the resultant bone dose would be about 30 mrem or 2 percent of the standard.

Table 14. Average phosphorus-32 and zinc-65 concentrations[a] in muscle of river birds, 1968

Species	Concentration (pCi/g)	
	Phosphorus-32	Zinc-65
Duck	53	3.3
Goose	1.4	1.5
Quail	41	3.5
Pheasant	10	4.9
Chukar	10.1	5.2

[a] Collected within 5 km (3 miles) of the Columbia River within the Hanford boundary.

Data from a dietary survey of Hanford employees and from a special survey of local hunters and concentration data for the various species have been combined in tables 15 and 16 (*4, 5, 10*).

Table 15. Distribution by species of local game birds, 1968

	Duck	Goose	Quail	Pheasant	Grouse	Dove
River birds[a] of each species	37	32	19	33	8	20
Meals of each species of all bird meals	23	6	12	47	13	ND
River bird meals of each species of all bird meals	8.5	1.8	2.3	16	<1	ND

[a] River birds are defined to be birds shot within 5 km (3 miles) of the Columbia River between Ringold and McNary Dam.
ND, no data.

About 30 percent of the game bird meals consumed by local hunters were reported to be birds shot within about 5 km (3 miles) of the Columbia River between Ringold and McNary Dam. Analyses showed that pheasants collected beyond this distance contained little if any radioactivity of Hanford origin. About 44 percent of all birds eaten were reported to have been placed in frozen storage which would permit appreciable decay of phosphorus-32 before consumption.

Table 16. Contribution of each species to 100 grams of an average game bird meal,[a] 1968

Species	Weight (grams)	Radionuclide content (pCi/g)	
		Phosphorus-32	Zinc-65
Duck	23	252	28
Goose	6	2	3
Quail	12	52	8
Pheasant	47	91	76
Grouse	13	5	5
Total	100	402	120

[a] Weighted for location of kill by using measured concentrations for river birds and assuming no phosphorus-32 or zinc-65 in other birds. Also weighted for frozen storage by assuming complete decay of phosphorus-32 but no significant decay of zinc-65 during frozen storage of 44 percent of the birds.

The maximum total game bird consumption by adults reported to date is 100 meals per year, which we assume to be about 23 kg/a. Consumption of this weight of the average game bird meal (table 15) would result in intakes of 0.09 μCi phosphorus-32 per year and 0.04 μCi zinc-65 per year, implying 14 mrem to the skeleton of a "standard man" or 1 percent of the standard for individual members of the population with bone as the critical organ. Consumption of the estimated annual intake (1.24 kg/a) for the "average Richland resident" (adult) would result in a total dose of less than 1 mrem to the skeleton.

Radionuclides in shellfish

Zinc-65 and phosphorus-32 are the only radionuclides in the reactor effluent that are found in sufficient abundance in food organisms beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of zinc-65 than other common seafoods (*11*). Monthly average concentrations of zinc-65 and phosphorus-32 were periodically measured in oysters grown commercially in the Willapa Bay area. A normal seasonal minimum for phosphorus occurs in the late summer. In 1968, phosphorus-32 average

concentrations remained at or below 1 pCi/g and from August through December as in 1967. The annual average concentrations for 1968 were 25 pCi zinc-65/g and 3.3 pCi phosphorus-32/g.

Consumption of oysters containing the 1968 average concentrations at the rate of 50 g/day would result in annual doses of about 5 mrem to the GI tract, 3 mrem to the whole body, and 8 mrem to the bone of a standard man (*12*, *6*). Fresh shellfish are not an important item in the average tri-cities diet, but residents of some coastal areas may consume more than the reference value of 50 g/day. For such individuals, shellfish are assumed to be their only source of radionuclides of Hanford origin.

Radionuclides in milk and produce

Irrigation with river water containing reactor effluent radionuclides can influence the radioactivity found in locally grown products. Deposition of airborne materials from Hanford sources and from fallout can be an additional source of radionuclides in these products. Chemical separations facilities are generally the principal local source of airborne radionuclides, although radioactive materials released from ventilation stacks of reactor or laboratory facilities could, under certain conditions, be of interest.

The farming area closest to the separations facilities is at Ringold about 21 km (13 miles) away. However, much of the land east and south of the project boundary is under cultivation and may be in the path of airborne release.

Most irrigated farms near the Hanford plant obtain water from the Yakima River or from the Columbia River above the plant. However, two small irrigated areas using Columbia River water taken downstream from the reactors are the Ringold farms and the Riverview district west of Pasco. They are 40 to 65 km (25 and 40 miles), respectively, downstream from the operating reactors. The Ringold farms, about 21 km east of the separations areas, involve some 20 people working 2 km^2 (500 acres) of land with fruit as the principal product. The Riverview district comprises about 21 km^2 (5,300 acres) supporting about 1,000 families, the majority of which live on plots of 4,000 m^2 (1 acre) or less and raise family gardens. The principal products from the larger farm plots are hay, fruit, beef, and diary products. This area is centered 40 km (25 miles) southeast of the chemical separations plants.

The milk surveillance program maintained during 1968 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. The concentrations of radionuclides found in milk sold by commerical outlets were similar to those reported by the U.S. Public Health Service and the Washington State Department of Health (*13*, *14*). Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus-32, zinc-65, and iodine-131, as well as fission products of fallout origin. Commercial milk distributed in the tri-cities usually does not contain detectable phosphorus-32 and zinc-65 because the majority of the milk is produced on farms not irrigated with Columbia River water.

During 1968, the annual average phosphorus-32 concentrations was 450 pCi/liter compared to 320 pCi/liter in 1967 as a result of inclusion of another sampling location in 1968. The 1968 annual average concentration of zinc-65 was 340 pCi/liter compared to 200 pCi/liter for 1967. Seasonal fluctuations in concentrations of both phosphorus-32 and zinc-65, caused primarily by irrigation and feeding practices, followed expected trends.

During 1968, iodine-131 concentrations in both farm milk and commercial milk were generally near or below the analytical limit (3 pCi/liter). The maximum iodine-131 concentration for the period (25 pCi/liter) was measured in a single sample of farm milk collected on January 17 and was attributed to increased worldwide fallout. The average concentration for the year in farm milk was <1.5 pCi iodine-131/liter.

Adult residents consuming milk (1 liter/day) obtained from the Riverview area could have received an annual dose from phosphorus-32 and zinc-65 amounting to about 4 mrem to the GI tract, 2 mrem to the whole body, and 32 mrem to the bone. The same intake of milk by a child with a 2 kg skeleton would result in an estimated bone dose of 110 mrem.[11] The intake of iodine-131 would have resulted in a dose of about 9 mrem to the 2 g thyroid of an infant.

[11] Based on dose factors of 660 mrem/μCi for phosphorus-32 and 11 mrem/μCi for zinc-65 for the 2 kg skeletal weight.

Miscellaneous fresh produce from local farms was sampled periodically for radioanalysis during the 1968 growing season. Results of these measurements were similar to those of previous years and indicated that only small quantities of radionuclides are present in locally grown produce.

Specifically, the concentrations of iodine-131 found in samples of fresh leafy vegetables collected from local farms and markets during the period of May through September were less than or approximately equal to the analytical limit of 0.05 pCi/g. Based on an assumed average concentration of one-half the analytical limit and the consumption of 100 g/day throughout the year, the annual intake from this source would have been about 380 pCi of iodine-131. Such an intake would imply an annual dose of about 0.6 mrem to the thyroid of an adult. Consumption of 50 g/day of the same vegetables by a small child would imply an annual dose of about 4 mrem to a 2 g thyroid.

External radiation

Ionization chambers (Victoreen stray radiation chambers) stationed on the Hanford reservation and in Richland measure the gamma radiation exposure from external sources. Measurements in air 1 meter above ground level during 1968 averaged about 0.36 mR/day or 130 mR/a at Hanford and 0.28 R/day or 100 mR/a at Richland. These were not significantly different from 1966 or 1967 values. Essentially all of the exposure at Richland is from natural background and worldwide fallout from nuclear testing.

Estimates of the external radiation dose received from recreational use of the Columbia River in the vicinity of the Hanford project is made from routine measurements at the river shoreline and below the surface of the river. The shoreline measurements are made with a large (40 liter) ionization chamber centered at 1 m (about 3 feet) above the ground to approximate the dose to the gonads.

The measured radiation includes components from radioactivity accumulated in sediment deposits and algal growths on the substrate at the river's edge. Gamma spectra show that scandium-46 and zinc-65 were the major contributors to the shoreline component and sodium-24 to the water component during 1968. The external exposure rate to swimmers, water skiers, and fishermen using the Columbia River in the tri-cities areas is predominately due to gamma rays of the order of 1 MeV or greater.[12] The shoreline radiation levels are affected by both the daily and seasonal fluctuations in the flow rate and river level.

The primary fishing locations for the panfish species consumed in the largest quantities are downstream from Richland, and the average dose rate for such fishermen is determined best from measurements at Sacajawea Park. During 1968, the average exposure rate at Sacajawea Park was 0.65 mR/day (27 μR/h) with an estimated 0.19 mR/day (8 μR/h) due to natural background radiation. An avid fisherman standing on the river shoreline at Sacajawea Park for as much as 500 hours during the year would have had a gonad and torso exposure to gamma radiation of about 10 mR (2 percent of standard for whole body), not including natural background radiation.

Direct radiation measurements also are made in the Columbia River at several locations with clusters of five pocket-type ionization chambers positioned about 1 meter (3 feet) above the river bottom. Exposure rates are primarily due to the gamma emitters (especially sodium-24) introduced into the river with reactor cooling water. In the vicinity of Richland, the average exposure rate in the water from April through October of 1968 was about 1.5 mR/day.

During 1967, the whole-body dose received by the average Richland resident from recreational use of the Columbia River was based on an estimated 24-hour immersion exposure time and was about 2 mrem. During 1968, a slightly different approach was used.

Teenagers were considered to be the major recreational users of the river. A recent survey of 430 Richland teenagers indicated an average exposure time for this group of about 115 hours of which about one-third of the time was probably immersion and about two-thirds was shoreline exposure.[13]

Using the annual shoreline exposure rates at Richland of 0.91 mR/day or 0.038 mR/h (not including background radiation) and the April-October average immersion exposure rate of 1.5 mR/day or 0.062 mR/h, the average exposure to

[12] Unpublished shoreline data by D. H. Denham, Battelle-Northwest, Richland, Wash. (1969).

[13] Unpublished recreational use data by J. F. Honstead, Battelle-Northwest, Richland, Wash. (1969).

the teenage population was estimated to be about 5 mR during 1968.

Some teenagers reported considerably greater exposure time than the average. The 38 teenagers reporting greater than 300 h/a total of Columbia River recreation time were taken to be a representative sample of the critical population group for this exposure pathway. The estimated annual whole-body doses for individual members of this group ranged from 6 to 37 mrem with an average of about 17 mrem compared to the appropriate standard (500 mrem/a). This represents less than 4 percent of the standard.

The average whole-body dose received by the Richland population from recreational use of the Columbia River can be estimated by assuming that other age groups use the river less than teenagers but with the same proportion of immersion and shoreline exposure times. Based on 11 hours of immersion and 21 hours of shoreline exposure in the vicinity of Richland, this whole-body dose during 1968 was estimated to be about 2 mrem, less than 1 percent of the appropriate standard of 170 mrem/a.

For comparison, if the recreational dose received by Richland residents were estimated for 1968 by the methods used in previous reports, the resulting whole-body dose would also be about 2 mrem.

Fallout from nuclear weapons tests

Dose increments received by residents of the Hanford environs from the fallout nuclides; tritium, strontium-90, and cesium-137 have been estimated routinely, although they are not included in the assessment of dose due to Hanford operations. Locally, this increment is below the national average because of the low rainfall. Measurements of fallout, like measurements of natural background radiation, help to put the radiation doses resulting from Hanford operations in proper perspective.

During the early influx of fresh fallout in 1968 following a foreign weapons test in December 1967, the peak iodine-131 concentration in milk was 25 pCi/liter compared to 83 pCi/liter in January 1967, following a foreign weapons test of December 1966.

Estimates of tritium intake from drinking water were based on concentrations measured in river water. Strontium-90 in locally available milk averaged slightly above 4 pCi/liter during 1968 and slightly below that in 1967. Concentrations of cesium-137 in locally available milk were generally near the analytical limit of 30 pCi/liter during both 1968 and 1967. Worldwide fallout is the source of strontium-90 and cesium-137 in milk.

Using the assumption that 40 percent of the total strontium-90 intake from fallout is obtained from milk, the daily intake of strontium-90 during 1968 was about 10 pCi/day for the "maximum individual," 10 pCi/day for the "typical Richland resident," and 5 pCi/day for the "average Richland resident" (adult) (*15*). These values are similar to the intakes estimated for 1967 (8, 9, and 5 pCi/day, respectively). The total intake of cesium-137 during 1968 was about 0.06 μCi for the "maximum individual," 0.01 μCi for the "typical Richland resident," and 0.01 μCi for the "average adult Richland resident." These intakes are also similar to those for 1967.

Tables 17 and 18 show a summary of the estimated annual doses from fallout nuclides present in the Hanford environs. The strontium-90 intakes are also evaluated in terms of the Federal Radiation Council guides (*16*).

Table 17. Annual radiation dose from fallout radionuclides,[a] 1968

Radionuclide	Organ	Radiation dose (mrem)		
		"Maximum" individual	"Typical" Richland resident	"Average" Richland resident
Tritium	Whole body	<1	<1	<1
Strontium-90[b]	Whole body	3	3	2
	GI tract	<1	<1	<1
	Bone	35	35	18
Cesium-137	Whole body	2	<1	<1
	GI tract	<1	<1	<1
	Bone	4	1	1

[a] Not included in dose summaries presented elsewhere.

[b] The values listed for dose to bone and whole body from ^{90}Sr are based on the assumption of an equilibrium situation, although such equilibrium would be approached only after many years of continuous intake. Average intakes for the "maximum" individual, the "typical" Richland resident, and the "average" adult Richland resident correspond to 2 percent, 5 percent, and 3 percent of the FRC guide (*23*) of 200 pCi/day for the average intake by a suitable sample of the exposed population or 600 pCi/day intake by an individual.

Table 18. Total annual radiation doses from fallout radionuclides, 1967–1968

Organ	Radiation dose (mrem)					
	"Maximum" individual		"Typical" Richland resident		"Average" Richland resident	
	1967	1968	1967	1968	1967	1968
Whole body	5	5	3	4	2	3
GI tract	<1	<1	<1	<1	<1	<1
Bone	34	[a]40	32	36	19	19

[a] Number was rounded after summing contributions of strontium-90 and cesium-137.

Composite estimates of radiation dose

The "maximum individual"

Experience accumulated from the environmental surveillance program and associated research studies indicates that those individuals receiving the greatest percentage of permissible radiation dose from Hanford sources consume some combination of the following: fish caught locally in the Columbia River; game birds shot near the river; foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors; and municipal water with the Columbia River as the source. A hypothetical "maximum" individual has been assigned assumed dietary habits (table 19) which are identical to those used in the 1966 and 1967 annual reports (*17, 5*) and have been documented separately in detail (*18, 19*).

The consumption rates of most foods for this hypothetical "maximum" individual were compiled from intake rates described in published dietary surveys. The postulated sources include water from the Pasco municipal system, milk, meat, and produce from river-irrigated farms in the Riverview district. The consumption of 200 meals per year of panfish taken from the Columbia

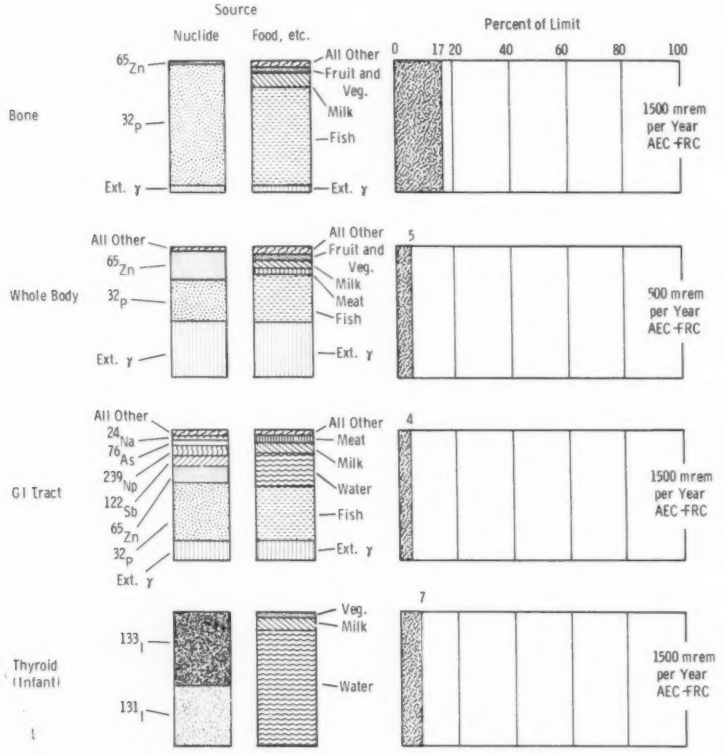

Figure 7. Estimated doses to the "maximum" individual, 1968

Table 19. Dietary assumptions, 1968

Foodstuffs	"Maximum" individual	"Typical" (adult) Richland resident	"Average" (adult) Richland resident
Water	730 liter/a	440 liter/a	[a]680 liter/a
Milk	380 liter/a	310 liter/a	[a]130 liter/a
Meat	80 kg/a	80 kg/a	[a]74 kg/a
Chicken	8 kg/a	5.4 kg/a	[a]5.4 kg/a
Eggs	30 kg/a	15 kg/a	15 kg/a
Seafood	0	[b]5.5 kg/a	[ab]1.4 kg/a
Columbia River fish	40 kg/a	0	[a].48 kg/a
Game birds	0	0	[a]1.2 kg/a
Leafy vegetables	[c]73 kg/a	36.5 kg/a	36.5 kg/a
Other vegetables and fruits	[c]530 kg/a	[d]200 kg/a	[d]200 kg/a

Foodstuffs	"Maximum" individual (infant)	"Typical" (infant) Richland resident	"Average" (infant) Richland resident
Water	0.8 liter/day	0.4 liter/day	0.4 liter/day
Milk	1.0 liter/day	.6 liter/day	.6 liter/day
Leafy vegetables	50 g/day	25 g/day	25 g/day

[a] Based on dietary questionnaires of Richland residents employed at Hanford.
[b] One-tenth of the total is assumed to be Willapa Bay Oysters, the remainder free of radionuclides of Hanford origin.
[c] Fresh produce from the Riverview area is assumed to be available only during 5 months of the year.
[d] The previous report erroneously quoted 35.5 kg/a instead of 200 kg/a.

River is based on the maximum reported in local surveys. A total of 500 h/a along the riverbank to catch these fish is also assumed.

The composite dose for this "maximum" individual is summarized in table 20 and illustrated in figure 7. The estimated dose to the GI tract for the "maximum" individual during 1968 was about 62 mrem or about 4 percent of the appropriate standard, which is slightly lower than the 1967 GI tract dose which was about 5 percent of the standard. The whole-body dose estimated for 1968, 24 mrem or about 5 percent of the appropriate standard, was somewhat lower than the 1967 estimate of 32 mrem (6 percent of standard).

Table 20. Summary of radiation doses in the Hanford environs,[a] 1968

Organ	Annual dose (mrem)	Standard (mrem)	Percent of standards
Maximum individual:			
Bone	250	1,500	17
Whole-body	24	500	5
GI tract	62	1,500	4
Thyroid (infant)	110	1,500	7
Typical Richland resident:			
Bone	8	500	2
Whole-body	3	170	2
GI tract	24	500	5
Thyroid (infant)	55	500	11
Average Richland resident:			
Bone	13	500	3
Whole-body	3	170	2
GI tract	25	500	5
Thyroid (infant)	39	500	8

[a] Doses from fallout and natural background not included.

The estimated percent of the maximum permissible rate of intake (for ingested radionuclides) with bone as the critical organ was 9 percent during 1968, compared to 12 percent during 1967, and 10 percent during 1966. However, for purposes of this report, an estimated bone dose of 250 mrem (17 percent of the FRC Standards) was derived from radionuclide intake and included a contribution from external radiation.

In the case of the thyroid gland, the highest radiation doses are those received by infants because of the relatively small thyroid mass (assumed to be 2 g). The "maximum" individual (infant) is defined as a Richland infant drinking Richland water with radionuclide concentrations equal to those at the water plant and consuming food and milk obtained from commercial sources. Dietary assumptions for 1968 (table 19) were identical to those used in 1967.

The estimated thyroid dose received by such a Richland infant in 1968 was 110 mrem (7 percent of the appropriate standard) which is somewhat greater than the maximum infant thyroid dose for 1967 (97 mrem or 6 percent of the standard).

The slight increase resulted from an increase in the estimated dose contribution from iodine-133 in drinking water in 1968. Measurements of grab samples of drinking water taken monthly at the Richland water plant during 1968 indicated a somewhat higher ratio of concentrations of iodine-

133 to iodine-131 (6:1) than had been assumed for 1967 (4:1). The annual average iodine-131 concentration in cumulative samples multiplied by the iodine-133 to iodine-131 ratio was the estimated average iodine-133 concentration. Based on the 1968 values, the iodine-133 in drinking water contributed 58 percent of the "maximum" individual (infant) thyroid dose.

For comparison with the "maximum" Richland infant, the thyroid dose estimated for a Riverview infant consuming foods from the same sources as the adult "maximum" individual was 79 mrem in 1968. This lower value reflects the lesser contribution of iodine-133 in Pasco water compared to Richland water.

Table 21 shows the trend of "maximum" individual dose estimates for the period, 1964–1968. The 1968 thyroid dose and bone doses have been adjusted to a comparable basis (from iodine-131 only). The increase observed in the thyroid dose during 1966 reflects an unusual release of radioiodine to the Columbia River from a production reactor (*17*). The long-term trend for whole-body and GI-tract doses is obviously downward. Bone doses for the "maximum" individual are heavily dependent upon phosphorus-32 in Columbia River fish which are, in turn, dependent on river conditions as well as radionuclide release rates. The lower 1966 estimate compared to 1965 and 1967 reflects to some extent the extended reactor outage of that year. The decreases to 9 percent MPRI in 1968 resulted primarily from decreased concentrations of phosphorus-32 in Columbia River fish.

Table 21. Dose estimates for "maximum" individual 1964 to 1968[a]

Organ	Percent of standards					Standard (mrem)
	1964	1965	1966	1967	1968	
GI tract	9	6	5	5	4	1,500
Whole-body	18	8	7	6	5	500
Bone	[b]23	[b]12	[b]10	[b]12	[b]9	—
Thyroid (infant)	5	4	6	[c]3	[c]3	1,500

[a] Does not include fallout and natural background.
[b] For comparison, expressed as percent MPRI of ingested radionuclides rather than as percent of standard including dose from external sources.
[c] For comparison, includes dose from iodine-131 only.

The "typical" Richland resident

The majority of people who live in Richland obtain their food from local commercial stores (rather than from farms) and consume little or no Columbia River fish or local game birds. The principal source of radionuclides of Hanford origin ingested by such people is drinking water obtained from the Columbia River. For continuity with previous years, the doses for several organs of the body for the "typical" Richland resident have been calculated for 1968. Table 19 shows the dietary assumptions for this group.

The estimated dose to the GI tract of the "typical" Richland resident from nuclides of Hanford origin during 1968 was about 24 mrem or 5 percent of the maximum permissible dose, the same as in 1967. Ninety percent of the GI tract dose was contributed by drinking water. The combined doses from intake of bone-seeking nuclides and external exposure was 8 mrem or about 2 percent of the appropriate standard (500 mrem) for a suitable sample of the exposed population. Similar radionuclide intakes corresponding to about 1 percent MPRI were observed for 1966, 1967, and 1968. The estimated whole-body dose of the "typical Richland resident" for 1968 was 3 mrem or 2 percent of the appropriate standards, slightly less than for 1967.

For comparison, whole-body doses from natural background (excluded from the FRC guide) and from fallout in this region are estimated for the "typical" Richland resident at about 100 and 4 mrem/a, respectively.

For dose to the thyroid, the most appropriate sample of the exposed population would seem to be Richland infants. Table 19 lists the assumed consumption rates. The water is from the municipal system (assuming radionuclide concentrations equal to those at the water plant), the milk is from commercial sources, and a few leafy vegetables in season are obtained from local markets. From these sources, a thyroid dose for the "typical" Richland resident (infant) was 55 mrem, or about 11 percent of the appropriate standard, including an estimated contribution of 31 mrem from iodine-133 in the drinking water. For comparison, the calculated thyroid dose for 1967 from the same sources was 27 mrem for iodine-131 only.

Figure 8 shows the source and nuclide contributions to the doses to various organs for the "typical" Richland resident, and table 17 presents a dose summary.

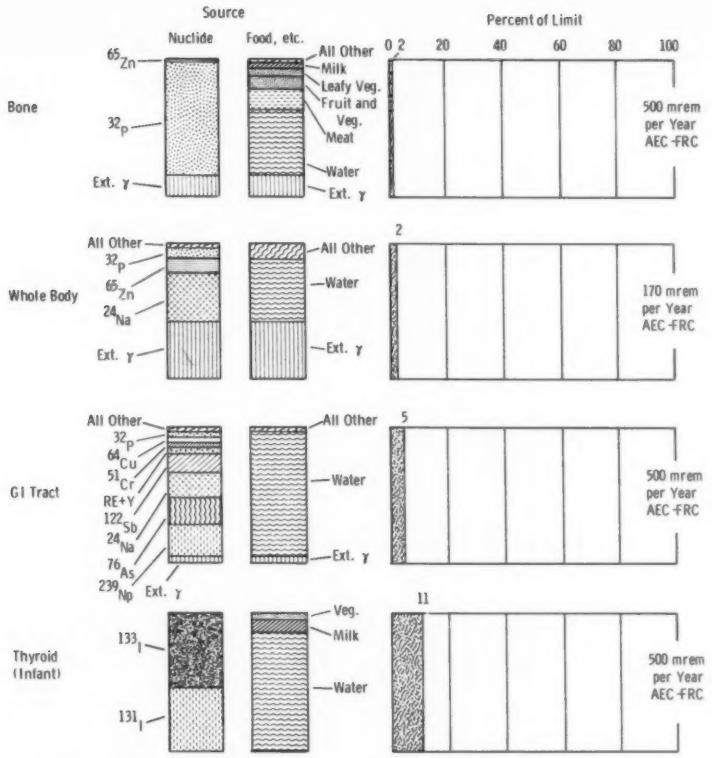

Figure 8. Estimated doses to the "typical" Richland resident, 1968

The "average" Richland resident

Estimates of average consumption rates of several food items were obtained for Richland adults from analysis of dietary questionnaires completed by plant employees. The program and the data have been discussed in another report (5). The principal changes from the consumption values assumed for the "typical" Richland resident were an increase of 55 percent for tap water (of which a substantial portion was consumed as coffee), a decrease of 58 percent for milk, a 75 percent decrease for seafood (one-tenth of which is still assumed to be Willapa Bay oysters), and the inclusion of 0.48 kg/a of Columbia River fish and 1.24 kg/a of game birds. Table 19 includes a summary of the "average" Richland resident's diet.

In computing doses for the "average" Richland residents, the assumed food sources were Richland drinking water with average concentrations adjusted for decay and dilution, Columbia River fish with the average species composition of fish ingested by the "maximum" individual, average game birds, milk, meat, and produce from local stores.

Because no significant contribution from Hanford operations to the background radiation levels in Richland can be discerned, the external dose to the adult "average" Richland resident is assumed to result only from recreational use of the Columbia River. An estimated annual dose increment slightly less than 2 mR from immersion in the river and activities along the shoreline was included in the GI tract, whole-body, and bone doses on the basis of a recent survey of Richland

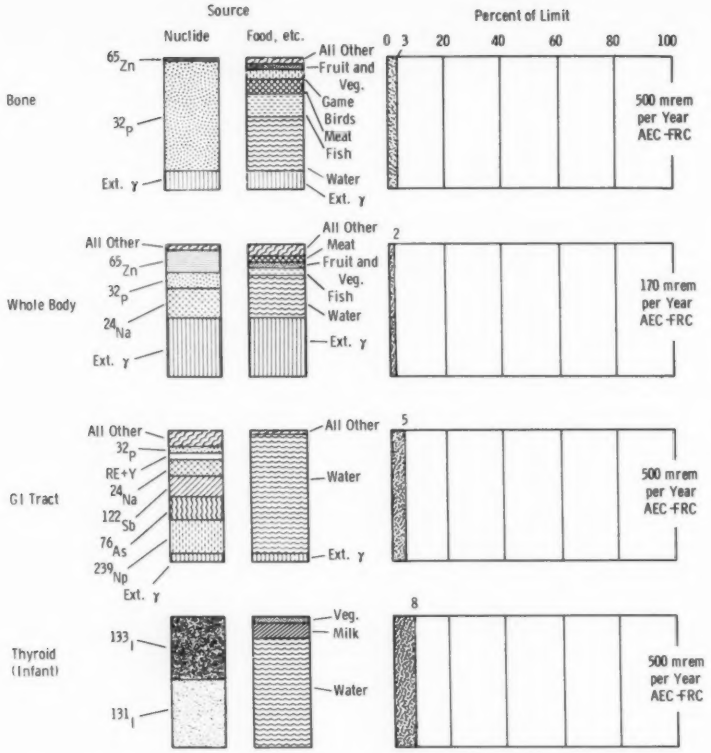

Figure 9. Estimated doses to the "average" Richland resident, 1968

teenagers and extrapolation of these data to the entire population.

The organ of the adult "average" Richland resident that received the highest percentage of the appropriate dose standard during 1968 was the GI tract at 25 mrem or 5 percent of the standard. The principal source (93 percent of the total dose) was drinking water. The whole-body dose from Hanford nuclides during 1968 was estimated to be about 3 mrem (2 percent of the standard), 46 percent of which resulted from recreational use of the Columbia River. The dose to bone was 13 mrem or about 3 percent of standard in 1968 including a dose from ingested radionuclides corresponding to about 1 percent MPRI in the terminology of past reports. About 41 percent of the total bone dose was derived from drinking water, 18 percent from fish, 13 percent from external radiation, 11 percent from meat, 8 percent from game birds, with 9 percent from remaining food items. A single radionuclide (potassium-32) accounted for 85 percent of the total bone dose. Dose estimates for the "average" Richland resident are illustrated in figure 9 and summarized in table 20.

As in the previous report, the infant "average" Richland resident was assumed to have the same food intakes and sources as were used for the infant "typical" Richland resident. However, use of an average composition of drinking water (adjusted for radioactive decay and dilution) resulted in a lower thyroid dose of 39 mrem or about 8 percent of the standard.

Conclusions

The results of the 1968 environmental surveillance program at Hanford again showed that the amounts of radionuclides as measured in the environs were well within accepted standards. The only estimates exceeding one-tenth of the appropriate standard were for the bone of the

hypothetical "maximum" individual (17 percent of the 1,500 mrem/a standard) and for the thyroid of the infant "typical" Richland resident (11 percent of the 500 mrem/a standard). Because of changes in the method of computation, these dose estimates for the environmental population are not completely comparable to 1967 levels, but on a comparable basis they would represent a decrease. Process improvements and the shutdown of plant facilities both have contributed to a decrease in environmental doses from 1965 to 1968.

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Reported Nuclear Detonations, May 1971

(Includes seismic signals presumably from foreign nuclear detonations)

There were no nuclear detonations or seismic signals reported by the U.S. Atomic Energy, Commission for May 1971.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U. S. nuclear detonations may be obtained upon request from the Division of Public Information, U. S. Atomic Energy Commission, Washington, D. C. 20545.

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

RADIOACTIVE WASTE DISCHARGES TO THE ENVIRONMENT FROM A NUCLEAR FUEL REPROCESSING PLANT. *J. E. Logsdon* and *J. W. N. Hickey. Radiological Health Data and Reports,* Vol. *12,* June 1971, pp. 305–312.

The Nuclear Fuel Services fuel reprocessing plant has been in operation since 1966 and has provided valuable experience in waste management problems related to this type of facility. The large quantities of radioactivity which must be controlled at a nuclear fuel reprocessing plant virtually eliminate discharge-and-dilution as a satisfactory method of disposing of radionuclides which concentrate through environmental media. Radionuclides such as strontium-90, ruthenium-106, cesium-137, cesium-134, cobalt-60, tritium, and krypton-85 have been found in environmental media around NFS. These indicate that pathways to the public do exist as a result of operation of the facility. However, studies to date have indicated that typical population doses in the vicinity of NFS are not significantly different from doses received in other portions of the State.

KEYWORDS: Nuclear fuel reprocessing plant, radioactive waste, quality, environment, New York.

CHARACTERIZATION AND CERTIFICATION OF HEALTH PHYSICS TECHNICIANS. *R. L. Kathren. Radiological Health Data and Reports,* Vol. *12,* June 1971, pp. 313–317.

Personal, educational, and occupational history was obtained from a survey of more than 300 health physics technicians. The "average" technician is a 36-year-old married male with about 10 years of experience in the nuclear field. About two-thirds are veterans. Half of the group have completed two or more years of college, and most received specific training in radiological health on the job. Because of the diversity of educational and occupational backgrounds, a voluntary certification program is proposed, with certification requiring passage of a written examination in addition to several years of experience and other requirements.

KEYWORDS: Certification, health physics technicians, radiological health.

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